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XI.—*On the Lower Palæozoic Rocks of the South-East of Ireland, and their Associated Igneous Rocks.*

By J. BEETE JUKES, *M A., F. R. S., &c. &c., and the* Rev. Professor HAUGHTON, *M. A., F. T. C. D., F. R. S., &c., &c.*

Read April 26, 1858.

INTRODUCTION.

THE following Paper is divided into two separate portions: one, Geological; and the other, Mineralogical. The first is written by Mr. JUKES, the second by Mr. HAUGHTON, both of whom visited together many of the most important localities described.

Sir RICHARD GRIFFITH contributed some of the information and specimens connected with Arklow and West Aston. The Rev. Professor JELLETT generously placed at Mr. HAUGHTON's disposal the sum of twenty guineas, by means of which the expenses incidental to the chemical analyses of the rocks described in the second part of the Paper have been defrayed. The Council of the Academy also allowed a sum of £20 for the purpose of illustrating Mr. JUKES's portion of the Paper.

PART I.

The Geological Relations of the Lower Palæozoic Rocks.

By J. Beete Jukes, M. A., F. R. S., &c. &c.

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The district which we propose to describe consists of the two counties of Wicklow and Wexford, with the adjacent parts of the counties of Dublin, Kildare, Carlow, Kilkenny, and Waterford. It is defined on the land side by an irregular line running from Howth Harbour to Ballyvoyle Head near Dungarvan, that line forming the boundary between the upper Palæozoic formations on the one hand, and the lower Palæozoic rocks on the other.

I. Stratified Rocks or Formations.

The lower Palæozoic rocks of the south-east of Ireland belong to two geological periods—the Cambrian, and the Cambro- (or Lower) Silurian.*

1. The Cambrian rocks consist of a great series of alternations of sandstones, or gritstones, and slates, having a total thickness of many thousand feet.

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* We think it advisable to adopt the distinctive term Cambro-Silurian (first suggested by Professor Phillips), in order to show that it is very distinct from the (so-called) Upper Silurian, and that they are not mere subdivisions of one formation, like upper and lower Lias, or upper and lower Chalk, but as distinct as Carboniferous is from Permian, Oolite from Cretaceous, &c.

The colours of these rocks are dull green and dull red, of many various shades, sometimes passing into yellow, brown, or purple.

Great beds of dull yellow or brown quartz rock are locally interstratified with them.

This series contains a peculiar, although a very scanty, assemblage of fossils, consisting of some small impressions of radiated Zoophytes, called Oldhamia by Professor EDWARD FORBES, and some very well-marked holes and impressions, left by Annelids of two kinds, one called Histioderma by Dr. KINAHAN, and the other Arenicolites by Mr. SALTER.

2. The Cambro- (or lower) Silurian rocks are likewise many thousand feet in thickness, consisting principally of an earthy clay slate, of a dark gray, blue or black, colour, occasionally becoming green or red, or variegated. Thin fine-grained gritstones are often interstratified with these slates, and occasionally a small assemblage of more thickly bedded grits may be seen, never, however, attaining the dimensions of those which are frequent in the Cambrian rocks. No beds of quartz rock are to be found interstratified with the Cambro-Silurian series, but large masses of contemporaneous trap (chiefly felstone) accompanied by beds of trappean ash, are to be seen in it, associated with other igneous rocks of an intrusive character.

Speaking generally, the Cambro-Silurian rocks of the south-east of Ireland contain but few fossils, but in particular localities fossils occur rather abundantly: those localities always being in situations which show them to belong to the central or upper parts of the series rather than to the lower.

The species of fossils found are such as prove the fossiliferous beds to be of the same age as those of the Bala and Caradoc series of North Wales, the palæontological evidence being thus in precise agreement with that to be derived from lithological structure.

The following lists of fossils will demonstrate this:—

1. From Slieveroe, near Rathdrum, county of Wicklow.

Stenopora fibrosa.
Chætetes petropolitanus.
Orthis testudinaria, O. Actoniæ.
Leptæna sericea.
Euomphalus perturbatus.
Tentaculites annulatus.
Calymene Blumenbachii.
Homalonotus bisulcatus.
Beyrichia complanata.
Trinucleus concentricus.

2. Carrickadaggan, county of Wexford.

Orthis Actoniæ, O. elegantula.
Echinosphærites aurantium.
Cybele arenosa, C. verrucosa.
Trinucleus seticornis, T. concentricus.
Lichas Hibernicus.

3. Newtown, county of Waterford.

Orthis simplex, O. subrotundus, O. elegantula.
Ogygia Portlockii.
Illænus Bowmanni.
Ampyx mammillatus.

4. Tramore, county of Waterford.

Orthis parva.
Strophomena grandis.
Calymene Blumenbachii? (? duplicatus).
Acidaspis Jamesii (or bispinosus).
Cybele verrucosa.
Phacops Brongniarti.
Encrinurus intermedius.
Remopleurides dorsospinifer.

Beneath the beds which contain those fossils is a great thickness of other similar beds devoid of fossils. It is possible, perhaps probable, that these lower beds are of the age of the Llandeilo flags of Wales.

Whether there be any part of the series corresponding in age to the still lower group of the Lingula flags is yet more doubtful.

If the Lingula flags be altogether absent from their proper place between the Cambrian formation and the Bala part of the Cambro-Silurian series, their absence may be accounted for in the following manner:—

In North Wales, where the Lingula flags are present, there is apparently a perfect conformability from the Cambrian rocks up to the Bala beds: in Wicklow, on the other hand, there is a complete unconformability between the Cambrian formation and the black slates of the Cambro-Silurian series. In the hills a little west of Ashford, the dark gray or black slates of the Cambro-Silurian series may be seen stretching across the upturned and denuded edges of a series of purple slates belonging to the Cambrian, and probably to the lower part of the Cambrian series.

The interval thus proved to have been occupied by a destructive action over the area which is now part of the county of Wicklow may have coincided, in whole or in part, with the interval occupied by forces of production in the deposition of the Lingula beds over the area which is now contained in the counties of Carnarvon and Merioneth.*

II. IGNEOUS ROCKS ASSOCIATED WITH THE TWO FORMATIONS MENTIONED ABOVE.

Although the Cambrian formation of our district contains large exhibitions of quartz rocks, which are believed to be sandstones altered by heat (whether dry or accompanied by water or steam), it is remarkable that it hardly ever has any true igneous rock associated with it.

A boss of epidotic greenstone a little south of Roundwood; a small vein of highly crystalline hornblendic greenstone at Graystones, county of Wicklow; a similar one at Cahore Point, county of Wexford; and a few small veins or dykes of greenstone about Howth Hill, are the only igneous rocks that have been observed in the Cambrian areas of our district.

No locality, either, is known in our district where Cambrian rocks can be seen in immediate contact with granite, nor even in very close proximity to it.

The case is very different with regard to the Cambro-Silurian formation. It has been already said that this contains a large assemblage of contemporaneous traps. These are principally felstones; they are known to be contemporaneous partly by their bedded character and their analogy with contemporaneous traps elsewhere, partly by their being always associated with large masses of "ash," which occasionally become brecciated or conglomeritic, containing small and large, angular and rounded, fragments of trap and of slate, embedded in a fine, sometimes pulverulent, felspathic base.

There is, indeed, almost every gradation to be found, from a black slate into a gray, from that into a pale gray or green slightly felspathic slate, with a soapy feel; from that into a fissile "ash" or slate composed entirely of felspathic materials (with or without fragments of other rocks), and from that into a hard compact felstone, with shining facets of felspar crystals; and thence into a crystalline felstone, in which crystals of both felspar and quartz make up the mass of the rock.

This latter highly crystalline felstone may often be intrusive, or partly intrusive and partly contemporaneous, and there are somewhat similar rocks which occur always as intrusive veins or dykes, forming the "elvan" dykes, which pass directly into a variety of granite.

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* See Paper in vol. vi. of "Journal of Geological Society of Dublin," by Messrs. JUKES and WYLEY, "On Structure of North-Eastern Part of the County of Wicklow."

Associated with the contemporaneous felstones and ashes are large masses of greenstone of several kinds, which appear from their irregularity of outline to be of more exclusively intrusive character than the felstones. Some of the associated "ashes," however, resemble those of greenstone rather than of felstone, rendering it probable that some at least of the greenstones are likewise of contemporaneous formation. Other masses and veins of greenstone also occur, at a distance from any other igneous rocks, and clearly of subsequent and intrusive origin.

Besides these, which we may call, for distinction's sake, trap rocks, granite also occurs largely in our district :—

1. As a large connected mass, exhibiting a great continuous surface, and completely independent of any other igneous rock :
2. As a number of small detached masses appearing here and there at the surface, in more or less connexion with, or at least in near proximity to, the trap rocks :
3. At the south-eastern extremity of our district, forming apparently part of another considerable independent mass, a great portion of which, however, is covered by the sea.

All the granite now to be seen at the surface is of intrusive character and of later date than the lower Palæozoic beds with which it comes in contact, as is proved by its sending veins into them, and by its having converted them into metamorphic schists.

We may, however, perhaps, be allowed to speculate on the probability of molten granite having existed at no inaccessible distance beneath the surface, during the deposition of the Cambro-Silurian rocks, and look upon the contemporaneous felstones as being the superficial products of this molten granite, ejected either into the air, or into the seas, of those days.

If it could be shown that the beds penetrated by the small detached masses of granite mentioned above are considerably lower than the beds in which the contemporaneous felstones lie, we might, perhaps, be pardoned for suspecting that these detached bosses of granite formed part of the original molten mass from which the flows of felstone proceeded. In this case we might look upon the elvans, perhaps, as the pipes or feeders along which the molten matter travelled from the more deeply seated portions towards the surface. This view, however, is opposed by the fact that in no case can any direct connexion be now traced between the granitic masses and the felstones, and that, although the elvans are certainly most numerous in what we believe to be the lower beds, yet they never traverse those beds directly across for any great distance, but always run in lines parallel to the main strike of the rocks. They would seem, therefore, either to have been injected as horizontal sheets in among the beds before they were disturbed, or else as vertical or highly inclined dykes during or after the action of those forces which tilted the beds into their present highly inclined positions.

With regard to the main mass of granite, it would appear that subsequently to the deposition of the whole of the Cambro-Silurian rocks, some force acting from below caused this to swell upwards and intrude to some extent into the body of the rocks above. This upward intrusion of the granite would doubtless be accompanied by an elevation and an arching of the rocks above it, and indications are not wanting to make it probable that there was a simultaneous depression and sinking in of the rocks on each side of the elevated district.

It appears also probable that the surface of contact of the granite and the rocks over it was a very uneven and irregular one ; that not merely were there dykes and veins of molten granite injected into the adjacent rocks, but that its general outline was very irregular, large ridges, domes or mounds of granite, protruding upwards into the rocks above, with corresponding hollows, furrows, or basins, into which portions of the superincumbent rocks would necessarily settle down. Hence arise the present rather irregular outlines of the surface boundary of the granite and altered slate, and the detached patches of mica slate to be seen in the granite, and, as it were, dipping down into it. Sometimes this relation of position is carried so far as to produce the appearance of interstratified beds of granite and mica schist, alternating with each other, as described by Mr. WEAVER.*

Metamorphic Action of the Granite.—One result of this intrusion of the granite has been already alluded to, namely, the metamorphism produced on the rocks in the immediate neighbourhood of the granite. Our district affords admirable opportunities of studying this action to any one who has time to examine some large portion of it closely. Micaceous schists are always found in contact with the granite, sometimes, though rarely, passing into gneiss ; and often full of crystals of schorl, andalusite, and other minerals. As we recede from the granite, this crystalline character of the schist disappears, and finally fades away into that of the ordinary dull argillaceous slate of the rest of the country. The change from crystalline schist into clay slate is sometimes spread over the space of one or two miles ; sometimes takes place within one or two hundred yards. The altered character is always more extensive on the S. E. margin of the main mass of the granite than on the N. W. side, owing probably to the more rapid descent of the granite on the latter than on the former, since it often appears to undulate for some distance towards the S. E. at no great depth beneath the surface of the ground. The alteration along the edges of the smaller bosses of granite extends for a much less distance than that near the main mass —the extent to which metamorphism has reached always bearing a direct and obvious relation to the mass of the granite which has produced it.

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* "Transactions of the Geological Society," vol. v., first series.

III. PERIOD OF THE ACTION OF DISTURBING AND DENUDING FORCES.

During the time when this intrusive and metamorphic action of the granite was going on, the rocks were, doubtless, being affected by some of those forces of dislocation and disturbance, which then or afterwards tilted them into their present highly inclined positions, and communicated to them their present strike. It would be difficult, perhaps impossible, to determine whether the cooling and consolidation of the granite took place early in this period of disturbance, or was deferred till towards its close ; and equally difficult to determine, perhaps, what share the expansion from the heat of the granite alone, or the contraction consequent on its cooling, had in causing these disturbances.

We may, however, feel pretty certain that this cooling and consolidation were complete before the action of those denuding agencies had proceeded to any great length, which afterwards caused the granite to appear at the surface Everything we know or believe of the formation of granite compels us to suppose that at the period of its consolidation from a mass of molten matter into a crystalline rock it was still covered by at least some thousands of feet of other matter. The great covering of Cambro-Silurian rock, which still reposed upon the granite of the Dublin and Wicklow mountains after that granite was consolidated, must, of course, have been removed by an action of denudation of the same kind as that which has exposed at the surface of the earth the once deeply seated rocks of all other localities. It is, however, remarkable that in our district this amount of denudation had not only been begun, but almost completed, at a very early geological period, namely, before the commencement of the Carboniferous period.

The bare granite formed the floor of the sea in which the beds of Old Red Sandstone and Carboniferous Limestone were deposited, and the surface of the ground of the islands which rose from that sea ; just as bare granite would now form the bottom of the sea and the surface of the islands, if the Carboniferous rocks were stripped off, and the country depressed again a few hundred feet beneath its present level.

The present surface of the ground in our district is in many parts a very old surface; it existed very nearly in its present form before the deposition of the Old Red Sandstone. It was, however, once much more covered by an extension of the beds of the Old Red Sandstone and Carboniferous Limestone than at present ; as is proved by the existence of some outliers of those rocks beyond their general boundary. The most remarkable of these outliers is a patch of Carboniferous Limestone resting on Cambrian rock, at Taghmon, in the county of Wexford, six or seven miles from the nearest boundary of that formation.*

It is indeed probable that the present outline and contour of the ground of *the whole of* our district was very nearly what it is now, before the period of the Old Red Sandstone, any subsequent erosion and denudation having been very slight compared with that which had taken place previously to that period.

It follows from this, that, however intrusive some of the igneous rocks of the Lower Palæozoic district may be, and however much younger than the aqueous rocks with which they are in contact, yet, as there is nothing to warrant us in supposing them to have had an origin subsequent to the process of denudation, the whole of them are older than the Old Red Sandstone.

The Lower Palæozoic district must doubtless have partaken to some extent of the subsequent movements of disturbance which have affected the upper Palæozoic rocks of the immediate vicinity, and may have been more or less shaken and dislocated by all the disturbing influences that have vibrated through this portion of the globe since the Cambro-Silurian period. It must also have suffered to some extent by the denuding action which has swept away so large a portion of the Upper Palæozoic rocks from the immediate neighbourhood. One or two coats of greater or less thickness may have been removed from the hills; the present valleys may have been excavated from between those hills; the ravines and water-courses that traverse their sides may have been graven on them ; the present plains may have had their surfaces ground down to a little greater depth—in fact, a skin of a few scores, or in some places a few hundreds, of feet in thickness, may have been subsequently removed from the country. Nevertheless, the main fact remains, that the principal part both of the denudation and of the elevation and inclined position of the rocks of our district, had been produced previously to the deposition of the Carboniferous rocks, inasmuch as the latter repose at low angles, and in comparatively undisturbed positions, on the uplifted and eroded edges of the former.

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* See "Journal of the Geological Society of Dublin," vol. vi. p. 178.

It would seem probable also, from the absence of all formations of an age intermediate between the Carboniferous and the Pleistocene, that our district remained tranquilly above water during all the secondary and early tertiary periods, and was only once more bodily depressed below the sea at some late tertiary period.

IV. Position and Lie of the Rocks.

Although the denudation of the country had been nearly or entirely completed at so early a date, nothing is more remarkable in our district than the extent to which it has proceeded. Notwithstanding the very highly inclined position of the beds, and their numerous and large flexures and contortions, and notwithstanding the hardness and toughness of the materials of which they are chiefly composed, so greatly have they been denuded and worn down in order to produce the present surface of the ground, that they rarely form any continuous ranges of hills, or any other prominent external features, which assist us in drawing conclusions as to the position of the beds below the surface. Almost the whole of the county of Wexford is low, gently undulating ground, thickly and widely overspread with " drift;" and although Wicklow is more hilly, yet the hills composed of stratified rock are generally rounded and isolated mounds, separated by wide valleys, and low grounds, in which " drift" and superficial matters are largely accumulated. Good continuous sections, therefore, across the strike of the beds, or continuous exposures of rock ranging along the strike, are almost entirely wanting, and we have chiefly to trust to the collocation of many single detached observations for arriving at any knowledge as to the thickness of the formations, or the composition of their several portions.

The granite hills, indeed, seem at first view to be an exception to the above statement, since they form a continuous range of lofty land over a part at least of the district; but even this rock has been so largely denuded as to form a widespread expanse of low ground in the county of Carlow; and the broad valley of the Slaney cuts right across it, separating the granite hills of the Dublin and Wicklow Mountains from those of Mounts Leinster and Blackstairs on the borders of Wexford and Carlow.

In examining the position and lie of the rocks, therefore, our conclusions will principally be drawn from observing the boundaries of the several formations, and the directions of their subordinate groups of rock, as laid down on the maps, or from the collection and comparison of separate data, rather than from direct observations in the field.

The district divides itself naturally into seven areas that admit of separate description: three composed of Cambrian rocks; two of Cambro-Silurian; one of Granite ; and one partly of Granite, and partly of Cambro-Silurian rocks.

The Cambrian areas are:—A, that of Wexford; B, that of N. Wicklow; and C, that of Howth.

The Cambro-Silurian areas are:—D, that of Wicklow, Wexford, and Waterford; E, that of Kildare, Wicklow, and Dublin.

The Granite area is F, that which stretches from Dublin Bay to near New Ross.

The remaining area, G, is that south of Wexford Harbour, which we may call the Carnsore area.

A.—*The Wexford Cambrian district* stretches from the east point of Bannow Bay to Roney Point, three miles south of Courtown Harbour, its total length being thirty-six miles. It forms the Forth Mountain district near the town of Wexford, where it has a surface width of about seven miles, and attains, as its highest elevation, an altitude of about 700 (697) feet above the sea. Except on the Forth Mountain tract, it forms generally a low, gently undulating country, entirely covered by thick masses of sand, gravel, and marl, the Cambrian beds being only seen in detached quarries, or in low cliffs on the sea-shore, or on the banks of the Slaney for a few miles above Wexford.

Where seen, these beds are always found to be greatly contorted; the most frequent strike, however, being nearly N. E. and S. W. The north-western boundary of the area, as drawn on the map, has an average direction of N. 42° E., which may be considered as N. E. and S. W.

B.—*The Cambrian district of North Wicklow* commences about four miles north of Rathdrum, and extends to the valley of the Dargle at least, having a length of seventeen miles, and a width of seven or eight. Its western boundary, although rather irregular, has a strike of about N. 27° E. (nearly N.N.E.), whilst its south-eastern boundary, which is, however, believed to be a fault, runs N. 53° E., or N. E. ½ E.

This district forms a much greater extent of lofty ground than that of Wexford, having several hills of more than 1000, and one, namely the Great Sugar Loaf, of 1660 feet in height.

Its beds, accordingly, are often well seen, and several good sections, such as that of Bray Head, that of the Rocky Glen near Kilmacanoge, and those of Glenran, the Devil's Glen, and other places near Ashford, are to be seen in it.

In these and other sections continuous series of beds, several thousand feet in thickness, are shown, and the more conspicuous members of them may sometimes be traced across the country, continuously along the strike, for two or three miles, preserving the same dip and strike for that distance pretty steadily.

In every case, however, it has been found impossible to follow them out for a greater distance ; sudden and entire changes in the beds occurring, probably in consequence of great faults; or else an utter change in the direction both of dip and strike, and a confusion in the position of the rocks, arising apparently from numerous and complicated folds and contortions, combined with dislocations, so that, even if all the rocks were bared for an inspection, it would apparently be quite impossible to disentangle the confusion.

The most probable conclusions at which we can arrive from the study of these two Cambrian districts is, that in each case the lower beds are on the south and east, and the upper ones on the north and west, but even this vague conclusion is a very uncertain one. (See Sections 1 and 2.)

Two small slightly detached districts of Cambrian rock are to be mentioned in North Wicklow, the one forming Carrick Mountain, on the south-east of the area *B*, and the other making Carrickgolligan on the north-west of it.

The south-easterly one commences a little south of Ashford, and is six miles long, and not quite a mile in its greatest breadth. Carrick Mountain, 1260 feet in height, is its loftiest point. Both its beds and boundaries strike N. 53° E.

parallel to the south-eastern boundary of the adjacent main district. The beds, which consist of quartz rock interstratified with brown and purple slates, are apparently vertical, or nearly so.

The north-westerly outlier is much smaller, being not more than a mile and a half long, by a third of a mile in width. It is called Carrickgolligan on the Ordnance map, but is also known as Shankill. It rises to a height of 912 feet, both beds and boundaries striking N. 42° E., or N. E. and S. W.

C.—*The Howth Cambrian district* is nearly circular, and from two to three miles in diameter. It consists of great beds of quartz rock interstratified with green grits and green and purple slates. The beds are always highly inclined, but strike in such various directions with so much contortion and confusion as to render any further general statement as to their position impossible. They may be seen crumpled in a most remarkable way on the little island of Ireland's Eye, with the black slates of the Cambro-Silurian series obviously unconformable to them.

The irregularity and confusion to be observed in these Cambrian areas, and the impossibility of reducing them to order, and determining the original position and total thickness of the beds, arises, doubtless, from the number and magnitude of the disturbances by which they have been affected. When we recollect that they were already highly inclined, and greatly denuded and disturbed, before the deposition of the Cambro-Silurian rocks, having perhaps a general strike quite different from that subsequently impressed upon the district; and that, after the Cambro-Silurian beds were deposited horizontally across the edges of these highly inclined Cambrian rocks, *both* were affected by disturbing forces which have set the Cambro-Silurian rocks themselves into highly inclined, often into vertical, positions, and affected them with great dislocations, and probably with many complicated flexures,—we shall be at no loss to understand the difficulty of the attempt to unravel the confusion thus produced in the older of the two formations.

D.—*The Cambro-Silurian area of Wicklow, Wexford, and Waterford*, is the largest and most interesting of the seven into which our district is divided ; and might be said to include areas A and B. It is more than 100 miles in length from Killiney to Ballyvoyle Head, with an average width of fifteen or twenty miles.

If we examine the map, and observe the nearly straight north-west boundary of the Wexford Cambrian district, A, which, as before said, runs nearly true N. E. and S. W., we should see, at a distance of five or six miles from this boundary, and almost exactly parallel to it, a band of trappean rocks. These are the contemporaneous felstones mentioned before, together with a number of intrusive greenstones and other trap rocks.

In the intermediate band of country between the Cambrian boundary and these bedded trap rocks, we should find slates dipping in various directions, but generally either N. W. or S. E., and always at angles of 70° or 80°, if not at 90°, or vertical.

The only nearly continuous section is to be seen along the shore of Wexford, N. and S. of Courtown Harbour; and, judging from that and from other evidence elsewhere, we should say that the greatly contorted and minutely folded and crumpled Cambrian rocks are succeeded on the N. W. by thicker masses of Cambro-Silurian black slate, lying in very highly inclined and often vertical positions, and thrown apparently into bolder and larger, though equally abrupt, undulations.

If we take the average width of the band thus occupied by the lower beds of the Cambro-Silurian series as five miles, and suppose the total effect of these undulations to be equal to a double anticlinal folding of their whole mass, we should have one-fifth of the possible thickness as a measure of the actual thickness of these beds. This would give about 5000 feet as the probable thickness of the lower part of the Cambro-Silurian beds, those lying between their Cambrian base and the bedded traps. (See Section, No. 2.)

The bedded traps occur in two or three or sometimes more lines, very close together, the result either of as many distinct depositions, or of the reappearance of one or more bands at the surface consequent on the flexures of the rocks. If we assume one anticlinal fold here, it will give us obviously three lines of outcrop of the same beds, but we shall still be obliged to add two or three thousand feet to the 5000 already mentioned for this series of beds; and all the evidence goes to show that they dip as a whole towards the north-west under yet higher beds. Examining the country immediately to the north-west of this band of bedded traps and their interstratified slates, from the River Barrow below New Ross, right through the heart of Wexford to the neighbourhood of Gorey, a high north-westerly dip seems everywhere to prevail over a width of three or four miles, so that we are compelled to conclude that the bedded traps are themselves covered by a thickness of yet another three or four thousand feet, at least, of these higher rocks. This would give a total thickness of ten or twelve thousand feet for the Cambro-Silurian rocks. Farther to the north-west, the beds appear to be inclined pretty equally in both directions, and then, as we approach closely on the granite of Mount Leinster and Mount Blackstairs and the neighbourhood, the beds appear to be rising to the N. W., with a prevailing dip to the S. E. This south-easterly inclination on the flanks of the granite, however, has rarely so high an angle as is found to prevail at a distance from it. One circumstance is very remarkable,—that after the bedded traps have taken their final plunge to the north-west, they never reappear at the surface in that direction over the whole of the county of Wexford, and the adjacent parts of Carlow and Wicklow. We must therefore suppose that the beds in contact with the granite over all that portion of the area belong to the uppermost part of the Cambro-Silurian series of our district, that which lies above the traps.

The line of bedded traps before spoken of terminates on the coast at Tara Hill, about four miles north of Courtown. About four miles north of that again is Arklow Head, where there is to be seen a very interesting mass of bedded felstone ash, and ashy porphyry containing rounded pebbles, together with beds of trappean conglomerate, interstratified with slate rocks and associated with intrusive greenstones and elvan dykes.*

The general dip here is to the south-east; and from Arklow, all up the valley of Ovoca, and over all the country between it and the town of Wicklow, south-easterly dips, at a very high angle, are much more numerous than north-westerly ones. In this district, accordingly, we find the bedded traps reappearing at the surface in great force, as the beds rise towards the N. W., forming several lofty hills, and associated, as in Wexford, with intrusive greenstones and other igneous rocks.

From under this trappean series there rise, still farther to the north-west, the lower part of the Cambro-Silurian beds, like that between the traps and the Cambrian base in Wexford, and, as we should expect, we shortly find this Cambrian base itself appearing at the surface from underneath the Cambro-Silurian rocks, and forming the areas already described under the head B.

So far, then, the position and lie of the rocks in Wicklow and Wexford lead to harmonious results; they each point to the beds lying between Arklow

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* See Paper on Arklow Head by Mr. JUKES, Journal of the Geological Society of Dublin, vol. vii.

Head and Tara Hill, as the highest beds of the district; and we should conclude that these highest beds were those (so remarkably free from igneous rocks of all kinds) which strike N. E. and S. W. from near Arklow Head to near New Ross.

The results agree, too, in placing the contemporaneous traps, as a mass, in an intermediate position between these upper beds, and a lower set, the base of which reposes, whether unconformably or in apparent or real conformity, on the Cambrian rocks.

Another point in which they agree, also, is the number of small elvan dykes, which, both in Wicklow and Wexford, are found in these lower beds, intrusive into, altering, and slightly cutting across them, although always agreeing very nearly with them in general strike.

There is, however, now one curious discrepancy to be alluded to. If we suppose that the black slates of the Cambro-Silurian series, which rest directly on the Cambrian rocks, are always the lower part of that series (and we have no reason to make any other supposition), it then follows that the slates which lie between Rathdrum and Wicklow on the one hand, and Rathdrum, Glendalough, Roundwood, and Powerscourt, on the other, are the lower part of the Cambro-Silurian series, the part below the trap beds. These are the beds which in North Wicklow, from Glendalough to Killiney, are penetrated by the granite. We saw reason, however, just now, for supposing that the beds penetrated by the granite in Wexford were the beds above the traps. We ought, therefore, in walking along the margin of the granite from the one part of this district to the other, to come to some locality where the bedded traps themselves range up to the granite, and are equally cut through by it. The felstones of the neighbourhood of Rathdrum and Ovoca, striking from the N. E. to the S. W., ought, if they are continued, to range up to the granite somewhere about Tinahely. No such trappean group, however, is anywhere met with on the flanks of the main granite area F.

Looking at the persistency of the trappean group through Waterford and Wexford, everywhere dipping on the whole to the north-west, and at the reappearance of this group in part of Wicklow as the beds rise again in that direction and dip to the south-east, we can hardly avoid coming to the conclusion that before the rocks were disturbed, and while they remained horizontal, there was a continuous trappean group, with a thickness of two or three thousand feet, over the whole of the area D, and over at least the southern part of the area F, where the granite is now at the surface. On the supposition that the southern part of the granite has burst through this trappean group, leaving it still deep beneath the surface, we ought certainly, as we travel to the north and approach the part of the district where the lower beds gradually rise to the surface, to find this middle or trappean group cut across by the granite.

It is true that, trappean rocks being irregular and uncertain in their occurrence, they may not have been deposited or formed among the aqueous rocks which are penetrated by the granite about Tinahely, or in that part of the district, wherever it may be, where the beds with which the traps are contemporaneous are so penetrated.

This is one explanation of the difficulty, though not a very satisfactory one, and it is not rendered more satisfactory when we come to examine a little more in detail the contemporaneous traps of South Wicklow, and their associated beds, and the facts connected with their abrupt termination towards the south-west, or in the direction of the granite area.

In the country on the east and south-east of Rathdrum a great number of bedded traps and trappean ashes are to be seen interstratified with the slates, all dipping steadily at a high angle to the south-east, and striking to the south-west. Large, irregular, intrusive masses of greenstone also occur, but even these have their greatest linear extension parallel to the strike of the beds. These beds are three miles wide, measured across the strike, and whatever allowance we may make for reduplication of the beds by concealed folds or repeated dislocations, there must be a thickness of at least several thousand feet, almost one half of which apparently consist of the traps. But if we follow these beds along the strike to the south-west, the traps all suddenly disappear as soon as we come to a line running nearly N. and S. through Rathdrum, while in the country to the west and south-west of that line nothing but granite and elvan is to be found.

The largest mass of felstone on the north-east strikes directly at the granite of Ballinacarrig and Ballynaclash on the south-west, there being an interval of scarcely half a mile between the two rocks, and both form comparatively narrow bands running along the same line from N. E. to S. W. Farther to the south-west several other detached granitic masses make their appearance, that of Cushbawn and others near Aughrim all forming narrow bands at the surface, and all running from N. E. to S. W.

If again we look at the felstones of Ovoca, we should see great masses of trap interstratified with the slate continued for some distance to the N. E. by means of beds of felstone and beds of ash, but terminating quite abruptly on the S. W. at the very same meridian line mentioned before. Following on the strike to the south-west, no other igneous rocks are to be seen, but elvan dykes leading up to the large granitic mass of Croghan Kinshela.

In short, while the whole of this part of the country from Wicklow Head to Tinahely and Shillelagh has a persistent strike from N. E. to S. W., and a nearly persistent dip at a high angle to the S. E.; and while it is all equally full of various igneous rocks, running for the most part in narrow bands parallel to the strike of the beds, still, if we draw a N. and S. line through the town of Rathdrum, or very slightly to the west of it, all the igneous rocks to the east of that line are traps (felstone or greenstone), with many beds of trappean ash, and scarcely even a single elvan dyke, while all those to the west of that line are granites and elvans, without a single bed of compact felstone, or of trappean ash of any description, and with no other trap rock than some very highly crystalline greenstones on the south of Croghan Kinshela.

Two explanations might be offered of these facts:—

First, we may suppose the beds of aqueous rock to be the same throughout, and that the flows of molten trap and deposition of trappean ashes and debris were confined to the eastern side of the meridian line mentioned above, while the intrusion of igneous rocks at a subsequent period was confined to the west of that line.

Or we may suppose that the contemporaneous traps being confined as above, the subsequent intrusions of igneous rock only formed granitic masses in the one case where those traps were absent; while in the other, where they penetrated into the trappean group, they produced the greenstones of West Aston and other places. The difference of the two kinds of igneous rocks would in this case result from the difference of the materials with which they came in contact, the molten mass absorbing some additional bases in the eastern part of the district, so that the mass which elsewhere cooled into granite here became converted into greenstone.

It may however, be objected to this view, that while the granites of the western side are surrounded by a belt of slate metamorphosed into mica schist, the greenstones of the eastern are not so surrounded, and seem to have produced little or no alteration on the beds adjacent to them.

Secondly, we may suppose that the beds of the two parts of the district are not the same, but that the north and south line mentioned before as running through Rathdrum is a great line of dislocation, separating the one set from the other. In support of this view it might be mentioned, that if this line be continued to the north, it cuts the very abrupt S. W. termination of the Cambrian rocks of Carrick Mountain, and meets the great fault which is believed to run along the S. E. boundary of the Cambrian area B, that of North Wicklow. If continued still further north, moreover, it would appear to coincide for several miles N. and S. of Roundwood, with the boundary line between the Cambrian and Cambro-Silurian rocks, which might also be a fault.

Still, even this hypothesis does not relieve us from the difficulty, since, if this N. and S. line were merely a dislocation, we should expect to find the bedded traps *somewhere* on the western side of it, striking to the S. W. up to the granite; whereas, we not only do not find them in the band of country where we should expect them, but we do not find them at all either to the north or to the south of that band. We should still be left without any trappean set of beds anywhere on the margin of the main granite area, to mark the separation between the upper Cambro-Silurian beds in the centre of Wexford, and those which we must believe to be the lowest part of the Cambro-Silurian series, which rests on the Cambrian rocks on one hand, and the granite on the other, in the country running by Roundwood and Douce Mountain, from the Seven Churches up to Killiney.

We must, for the present at all events, be content to leave this puzzle, with others, still unsolved, and perhaps, from deficiency of data, for ever insoluble.

There is yet a part of this area, of which we must say a few words.

The band of bedded traps that stretch through Wexford into Waterford, receive in the latter county large accessions to their mass, and spread over a much greater width than they have in Wexford. So far as can be determined by the few scattered observations that can be made on their position, the whole formation still retains its former strike, and still dips from S. E. to N. W., and the traps plunge to the N. W. under a band of slates, in which few or no igneous rocks are to be seen.

It remains doubtful, however, whether the greater surface expansion of the traps in Waterford be due to a really greater thickness of these rocks, or to undulations and contortions in the rocks, or to repetition by means of faults. Perhaps all these influences may be combined to produce the effect.

E.—*The Cambro-Silurian area of Kildare and Wicklow* is separated from the preceding area D by the granite of the main area F. It occupies a space of about twenty-five miles in length, by seven or eight in width. The mean direction of its two longest boundaries is about N. 20° E. or N. N. E.; that of the two shorter nearly E. and W. It is remarkable that each pair of boundaries is parallel, although in both cases one boundary is the margin of the uprising and intruding granite, and the other that of the overlying unconformable Carboniferous Limestone.

The strike of the beds in this area is also parallel to that of its longest boundaries, or, almost without exception, N. N. E. and S. S. W. The dip of the beds on the immediate margin of the granite is W. N. W. at comparatively low angles, but over all the rest of the area the angle of inclination is very high, rarely less than 60°, and oftener 70° or 80°. It is very remarkable that although the flexures are apparently bold and numerous, the general tendency of the whole mass seems to be to dip *towards* the granite, the higher beds coming in in the direction of the granite, and the lower ones appearing to crop out on the north-westerly margin of the area.

The rocks, indeed, which strike from Kilcullen to Ballitore have, in their green and purple hues and gritty beds, no slight resemblance to some of the Cambrian rocks of areas A and B.

Numerous beds of trappean ash, generally resembling a greenstone ash, and often mingled with much sandy debris, are interstratified with the slates through the centre of the area, and towards the margin of the granite. Few masses of actual trap, however, occur till we reach the north-eastern limits of the area in the neighbourhood of Ballynascorney Gap, where large masses of coarse porphyry, containing dull green crystals of felspar, in a blue compact base, make their appearance. These seem to be clearly intrusive, and to produce some considerable amount of alteration on the adjacent slates.

F.—*The Main Granite Area.*—This is the largest exhibition of granite at the surface in the British islands, forming a continuous mass of seventy miles in length, with an average width of eight or ten miles, and a maximum in one part of eighteen.

Its eastern boundary is, with the exception of a few indentations caused by overlying slates extending into the granite area, very straight, running as nearly as possible N. N. E.

The western boundary of its northern half, though rather more irregular, is on the whole parallel to this, but about the centre of the area, or a little north of it, the boundary, in consequence of the deeper denudation of the granite, turns boldly to the west for seven miles. South of this deflection, which marks the entrance of the valley of the Slaney into the granite region, its western boundary is formed by the overlying Carboniferous rocks of Carlow and Kilkenny, resting upon it unaltered and undisturbed. This boundary is also very straight, running N. 14° E. and S. 14° W. for about eighteen miles, when the Cambro-Silurian slates again make their appearance, and wrap round the southern termination of the granite. This southern termination is by no means an abrupt one, and that the granite is continued for some distance towards the south-east at no great depth below the surface, is shown by the reappearance of two pretty considerable detached bosses of it, the latter being exhibited in the sides of the valley or glen of the Arrigle River, south of Thomastown, on the west of which the granite finally disappears under the almost horizontal beds of the Old Red Sandstone, which is there made up principally of granitic debris.

The loftiest point of the granite area, F, is Lugnaquillia, 3040 feet,* in the southern part of the county of Wicklow. It consists of a mass of mica schist resting on the granite. All the loftiest parts of the neighbouring mountains consist of similar patches of mica schist, and it is in this, the highest part of the granitic chain, that the mica schist most nearly meets over the granite, and the greatest number of patches and bands, and embedded masses of mica schist, are to be found within the granitic area.

This shows that it is in this, the loftiest part of the chain, that we have the original surface of the granite most nearly preserved, and that, if the mountains had been a little loftier,—in other words, if the denudation had not proceeded quite so far,—all these detached patches of mica schist would have been joined into a continuous mass, and a skin of mica schist would have spread completely over the granite.

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* This is also the loftiest eminence in the south-eastern quarter of Ireland.

Immediately south of this, on the other hand, where the ground is very low and the granite area is traversed by the valley of the Slaney, we have the widest exposure of granite at the surface, and find it to be most free from included patches of mica schist. We see in these facts how directly the appearance of granite at the surface is related to the occurrence and the extent of denudation.

It follows also from these and the preceding descriptions, that this main granite mass, however extensive it may be, and however it may form the most prominent and striking feature of our district, is yet not to be looked upon as either its geological or geographical axis.

North of Lugnaquillia, certainly, the granite hills form a watershed, between the affluents of the Liffey on the one hand, and those of the brooks that flow out on the coast at Arklow, Wicklow, and Bray, on the other. South of that mountain, however, the more important rivers, Slaney, Barrow, and Nore, run directly across the granite area from one side to the other, the whole drainage of the south-east of Ireland coming right across its strike.

Its geological relations are not more influential than its geographical.

We have already seen that the prevailing strike of the greater part of our district is as nearly as possible N. E. and S. W. The direction of the main granite band differs from this by an angle of 25°.

If the granite area served as a geological axis, we should, of course, always find the lowest rocks upon the flanks of the granite, and come upon higher and higher beds as we receded from it. So far from this being the case, it is the actual fact that the largest Cambrian area, that of Wexford, A, seems to stand especially aloof, both from the granite of the main area, F, and from that of Carnsore; while the Cambrian of North Wicklow (area B), although it is much nearer the granite, and at its northern extremity is quite close to it, is yet never brought up on the flanks of the granite, is not altered by it, has neither its beds nor its boundaries parallel to the direction of the granite, and, in short, seems in no way to be affected by it.

At the southern end of the area F, the granite is at a distance of twelve miles from the nearest Cambrian outcrop, and the beds in contact with the granite appear to be the upper part of the Cambro-Silurian series, that which is above the traps; while in North Wicklow the granite gradually approaches nearer and nearer the Cambrian outcrop, rising at last within a mile of it, and the beds in contact with the granite are apparently the lower part of the Cambro-Silurian series, those that rest directly on the Cambrian rocks.

It would appear, also, that under the waters of Dublin Bay the granite must come in contact with the Cambrian rocks themselves, cutting through those that lie between Bray Head and Howth Hill.

It is true that the beds and boundaries of the Cambro-Silurian area E (that of Kildare and Wicklow) run parallel to the direction of the longest extension of the granite area F; but even here it appears as if the granite cut into the higher beds, rather than brought up the lower beds of the series, and therefore does not serve as a geological axis.

All the evidence, in short, goes to show that the intrusion of the granite, both that of the main area, and that of the smaller detached bosses and bands of granite, though doubtless a powerful and forcible intrusion, was nevertheless an equable and gradual one, the molten mass working its way slowly upwards into the overlying beds, without producing any disturbance beyond its immediate sphere of action. Its motion would, perhaps, be more fitly described as a burrowing upwards, an undermining and eating its way up through whatever it chanced to meet with, rather than as a great elevating power lifting up the rocks above it, and rending them asunder, in order to burst a passage for itself towards the surface.

G. *The Carnsore Area.*—We have yet to say a few words on the district south of Wexford Harbour, that of Carnsore. This is separated from the area D by the Wexford Cambrian area A, and also by the overlying beds of Old Red Sandstone and Carboniferous Limestone, that stretch from Wexford Harbour to Ballyteigue Bay.

The area is one of very low ground, and the details of its geology are consequently very obscure. Both its beds and boundaries seem to strike about E. N. E. and W. S. W., the dip of the beds being generally at angles approaching the vertical. Graptolites were procured on the shore near Greenore Point, and several species of Bala fossils (Orthis, Pentamerus, &c.) were found in a small quarry north of Tagoat. Near that village, beds of red sandstone and conglomerate, exactly like Old Red Sandstone, were seen in a small quarry, interstratified with the slates of the Cambro-Silurian series. This fact makes it possible that the red sandstones and conglomerates of Bonmahon, county of Waterford, may in reality belong to the Cambro-Silurian rocks in which they lie, and not to any former covering of Old Red Sandstone, from which they were supposed to have been derived by downcast faults. In approaching the granite of Carnsore Point and Crossfarnoge, the Cambro-Silurian slates become metamorphosed into gneiss and mica schist, and are traversed by veins of granite and greenstone, and the granite itself is in some places also traversed by dykes of greenstone. This is especially the case on the Saltee islands.

The granite of this area differs in appearance from all the other granites of our district, being a coarse-grained red granite, with large crystals of flesh-coloured felspar. Small flakes of black mica are sparingly disseminated through it. A pencil-note on one of the Maps of the Geological Survey, in the handwriting, as believed, of Professor OLDHAM, mentions the existence at Carnsore Point of segregated masses of mica, sometimes as much as two feet long by one broad.

V. CLEAVAGE.

Although it would be travelling out of our limits to enter at large upon the subject of Cleavage, it would yet be wrong to pass it over altogether in silence.

Throughout our district, and indeed throughout the south of Ireland, all the Palæozoic rocks, both upper and lower, are more or less affected by slaty cleavage, from the Cambrian rocks up to the Coal-measures inclusive. The strike or direction of this cleavage is, with some few local exceptions, singularly uniform, scarcely ever differing from E. N. E. by so much as 10°. Cleavage with this strike is to be seen over all the country, from the county of Dublin to the extreme points of Cork and Kerry. Its dip, however, is not so persistent, being sometimes to the one side, and sometimes to the other, and varying greatly in amount; but in the Lower Palæozoic rocks of the S. E. of Ireland it is always at a very high angle, often vertical, or inclined at a few degrees from the vertical, either towards the N. N. W. or S. S. E.

In the fine-grained black slates of the Cambro-Silurian formation, the cleavage is sometimes carried out to such an extent as to obscure or even obliterate the stratification, and it is occasionally almost equally prominent in the Cambrian rocks. The cleavage, in fact, is often as fine and complete as in any slate whatever, and it only fails to make good roofing slate from the want of firmness in the material.

It would be a very difficult task in the S. E. of Ireland to arrive at any conclusions as to the relations between the strike and dip of the cleavage, and the anticlinal and synclinal curves into which the rocks have been thrown, inasmuch as it is impossible, as already stated, from want of continuous sections to determine those curves themselves with anything approaching to precision.

So far as can be observed in detached localities, it appears that there is here, as elsewhere, a general tendency to coincidence in the strike of the beds and the strike of the cleavage ; though if we judge by the direction of the boundaries of the areas of the formations, this coincidence seems by no means universal, nor, when examined on the great scale, to be anything more than approximate.

The general direction of the cleavage, on the other hand, so far as it can be determined by detached observations in particular quarries, coincides almost exactly with the strike of the Upper Palæozoic rocks in the S. W. of Ireland.

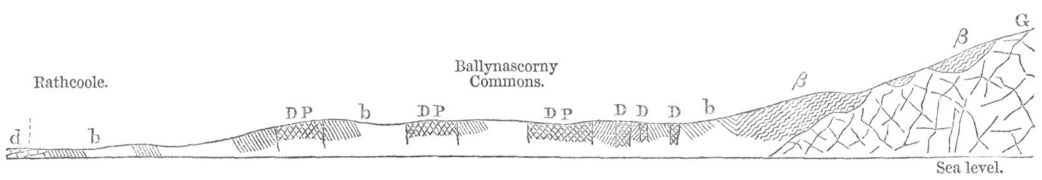
It remains a problem for future determination, by special research directed to that particular subject, whether the Lower Palæozoic rocks were affected by a slaty cleavage before the deposition of the Upper Palæozoic rocks, or whether the cleavage was impressed upon both simultaneously.

In the latter case it might have been produced by the forces which communicated the E. N. E., and W. S. W. strike to the rocks of the S. W. of Ireland ; while those forces, although they thus affected the S. E., may not have been sufficient to entirely change the direction of the previously existing strike of the rocks there.

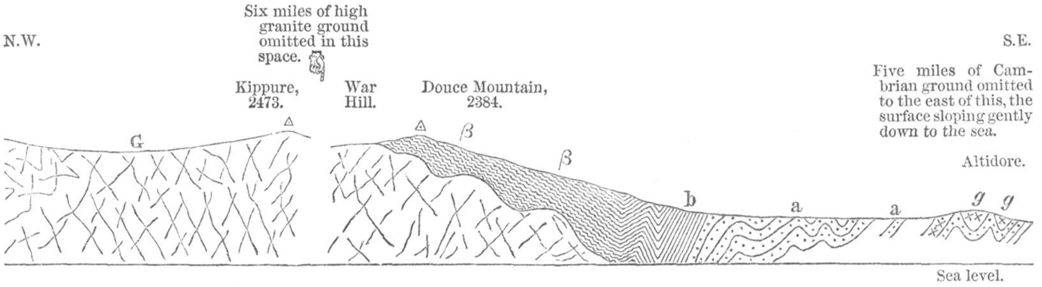
Some local exceptions, in which the strike of the cleavage runs E. S. E. and W. N. W., not coinciding with the general strike of the beds, make it possible, perhaps, that two cleavages may have been impressed upon the country.

There is also the possibility to be taken into account, that subsequent movements may have locally disturbed and shifted both the dip and strike of the cleavage after it was formed.—J. B. J.

Section No. 1.



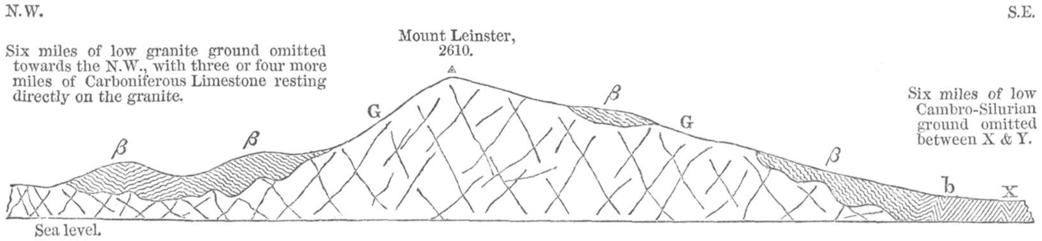
Section No. 1—*continued.*



Six miles of high granite ground omitted in this space.

Five miles of Cambrian ground omitted to the east of this, the surface sloping gently down to the sea.

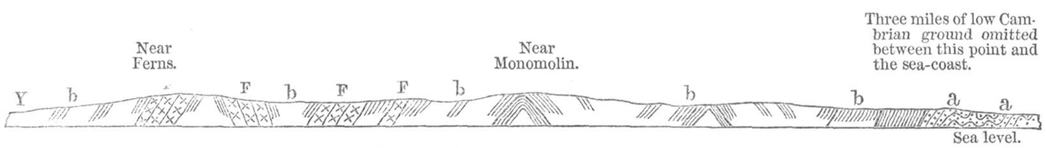
Section No. 2.



Six miles of low granite ground omitted towards the N.W., with three or four more miles of Carboniferous Limestone resting directly on the granite.

Six miles of low Cambro-Silurian ground omitted between X & Y.

Section No. 2—*continued.*



Three miles of low Cambrian ground omitted between this point and the sea-coast.

The anticlinal and synclinal folds into which the Cambro-Silurian slates and bedded traps are here thrown, are quite hypothetical in form and number.

d	Carboniferous limestone.	*g*	Quartz rock in Cambrian rocks.
b	Cambro-Silurian slates, &c.	D	Greenstone. P Porphyritic.
β	Altered do. (mica schist, &c.)	F	Felstone.
a	Cambrian rocks.	G	Granite.

Scale *of the* above *Sections*:—One inch to a mile horizontal, and two inches to a mile vertical; but not very strictly preserved, or the low grounds would not be seen above the sea horizon.

PART II.

Mineralogical Relations of the Igneous Rocks of the South-east of Ireland.

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The igneous rocks requiring description and illustration in the district we have under consideration are divisible into three groups: viz.—1st. The granitic axis, described as (F) in the preceding part; 2nd. The granitic rocks of Carnsore and the Saltees (G); and 3rd. The igneous rocks, granitic or otherwise, contained in the Cambro-Silurian region described as (D).

I. Granitic Axis of the District.

The granitic area is fully described at p. 583, *et seq.*, and will be best understood by a reference to the map. In addition to the area coloured on the map, it is probable that this granitic axis extends in a north-easterly direction under the sea, by Rockabill, off the north coast of the county of Dublin; and perhaps even extends as far as the granitic district of Creetown in Scotland.

A short mineralogical and chemical description of this granitic axis has been published in the twelfth volume of the "Quarterly Journal of the Geological Society of London." The account which is here given is illustrated by many additional analyses, which have thrown new light on some of the questions discussed in that description.

1. *General Description of the Granite.*—The granite of the axis, considered in its most complex varieties, is a quinary granite, containing the following minerals:—

1. Quartz (watery).
2. White orthoclase (distinct crystals).
3. Felspar (paste).
4. White mica (Margarodite).
5. Black mica (Lepidomelane).

Previous to discussing any particular analyses of the granite, it is necessary to say a few words respecting each of these constituent minerals.

2. *Quartz.*—The quartz of the granitic axis is the usual watery transparent quartz of all the Irish granites; it has a mean specific gravity of 2·645, as determined from many specimens taken from veins containing large fragments of quartz, accompanied by orthoclase and white mica, from localities in the counties of Dublin, Wicklow, and Carlow.

3. *Orthoclase.*—This felspar is invariably found in the veins containing large crystals, which are common, traversing the granite in every quarry that is opened, with very few exceptions. The orthoclase is accompanied in these veins by quartz and white mica, and occasionally by schorl, beryl, spodumene, apatite, fluorspar, and garnet; the latter, when it occurs, being always in small crystals; it is found more commonly than the other occasional minerals, which may be considered rare, except in particular localities.

Besides occurring in the large crystallized veins, orthoclase may readily be distinguished in facets and flattish surfaces, in the general felspathic paste of the granite of most parts of the axis. The composition of the orthoclase felspar of the axis has been studied with care by the Rev. Professor Galbraith, who has published the results of his analyses in the Proceedings of the Royal Irish Academy, vol. vi., p. 134. The following Table contains the results of Mr. GALBRAITH's experiments, which prove that the orthoclase of the different parts of the granite axis varies very little in its character:—

TABLE I.

Analyses of Orthoclase Felspar.

	1	2	3	4	5	6	7	Average.
Silica, ...	64·00	65·40	65·44	65·05	64·19	63·60	64·48	64·59
Alumina, . . .	18·11	17·71	18·36	17·72	18·39	18·84	19·04	18·31
Lime, ...	. .	. .	0·80	0·23	0·70	. .	. .	0·25
Magnesia, . .	0·57	1·77	. .	. .	0·34	0·40	1·02	0·58
Potash, . . .	12·73	10·68	12·34	13·42	11·39	14·33	10·74	12·23
Soda, ...	3·00	3·26	2·73	2·75	2·95	1·92	2·64	2·75
Loss by ignition,	0·55	0·69	0·52	0·36	0·58	0·60	0·78	0·58
Total, ...	98·96	99·51	100·19	99·53	98·54	99·69	98·70	99·29

No. 1.	Quarries of Dalkey, Co. Dublin,.	Specific gravity	= 2·540
No. 2.	Three Rock Mountain, Co. Dublin, ...	,, ,,	= 2·562
No. 3.	Lough Bray, Co. Dublin, ...	,, ,,	= 2·554
No. 4.	Lough Dan, Co. Wicklow,.	,, ,,	= 2·559
No. 5.	Glenmacanass, Co. Wicklow, ...	,, ,,	= 2·553
No. 6.	Glendalough, Co. Wicklow, ...	,, ,,	= 2·453
No. 7.	Glenmalure, Co. Wicklow, ...	,, ,,	= 2·560
		Mean	= 2·5401

All these felspars are monoclinic, and occur in large crystals, with their cleavage planes well developed ; the other faces are comparatively rare.

Taking the average per-centage, we find the following Table:—

TABLE II.

Atomic and Oxygen Ratios of the Orthoclase of Leinster.

	Atoms.		Oxygen Ratio.	
Silica, ...	1435		1435	3
Alumina, . . .	352		352	
Lime, ...	9			1
Magnesia,. . .	29	387	129	
Potash, . . .	260			
Soda, ...	89			
Water, . . .	64			

It will be observed that the protoxide bases are slightly in excess of the usual formula for this mineral, viz.:—

$$KO,\ Si\,O_3 + Al_2\,O_3,\ 3Si\,O_3\,; \qquad (1)$$

while the oxygen ratio gives very exactly the formula—

$$\left.\begin{matrix} Al_2\,O_3 \\ 3KO \end{matrix}\right\} 3Si\,O_3\,; \qquad (2)$$

understanding in both formulæ that KO denotes all the protoxide bases, as well as potash.

4. *Felspar of the Granitic Paste.*—I have not made any direct examination of the confusedly crystallized felspar of the granite paste, cementing the fragments of quartz, orthoclase, and mica together, nor do I believe it has a precise chemical composition constituting it a distinct mineral; it contains more soda than the orthoclase of the granite, in which we find only 2·75 per cent.

So far as I am aware, no crystals of either albite or oligoclase have ever been found in the Leinster granite, and this is easily accounted for by the fact, that the granite nowhere contains enough soda to admit of the formation of such crystals. There is not sufficient potash to form a felspar exclusively monoclinic in its form, nor is there sufficient soda to form the triclinic felspars; consequently, the orthoclase has crystallized out from the molten mass, leaving a confused residue of felspar to form the paste; this residue does not crystallize freely, as it is undecided whether to assume the monoclinic or triclinic form, and it, therefore, remains as a saccharoid paste of periclinic felspar.

The following partial analyses of this felspathic paste have been published:—

	Foster.*	England.*	Campbell.†	Campbell.†
Potash, . .	4·15	5·72	3·23	3·02
Soda, . . .	4·34	6·89	3·75	3·98

As all these specimens were taken from the same mountain,—the Three Rock Mountain, county of Dublin,—they are comparable with each other, and give for the average ratio of potash to soda in the felspathic paste of the granite of that mountain, picking out the mica and orthoclase—

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* Proceedings of Royal Irish Academy, vol. v., p. 381.

† Phil. Mag., Fourth Series, vol. ix., p. 513.

Potash, ...	4·03
Soda, ...	4·74

I shall compare this result with the composition of the felspar deduced by myself from calculation, a method which admits of very considerable accuracy.

I entertain grave doubts as to whether the felspathic paste of the granite is entitled to be considered as a distinct mineral, as it contains, as appears from the preceding estimate of alkalies, an insufficient quantity to form a tersilicated felspar, without the aid of the lime and magnesia, which exist in it in considerable quantity. It must be remembered that it is only by an arbitrary fiction of the mineralogists that we consider granite as composed of three, four, or two minerals. I shall show that the granite of Leinster unquestionably contains *four* minerals, viz., Quartz, Orthoclase, White Mica, and Black Mica, together with a confused felspathic paste, the composition of which may be ascertained, but which, being uncrystallized, except in a confused manner, we are at liberty to consider as a mineral or not, just as we please. It is as much a mineral as the chance slag of an iron furnace would be. No doubt, we may ascertain its chemical composition, and form a formula therefrom, but until it is found crystallized in a definite form we have no right to call it by the name of any recognised mineral ; it is neither orthoclase, nor albite, nor oligoclase, but a confused mass of felspathic paste, having a composition that is constant for many miles of superficial extent.

5. *White Mica.*—In every specimen of granite that I have seen from the main chain, white mica is abundant, and as it contains 5 or 6 per cent. of water, it becomes highly interesting, as its occurrence is a proof that during the formation of the granite, water must have been present, in order to be chemically combined with the silicates composing the mica. This water must have occurred at a temperature between cherry red and the melting-point of silver, between which limits the granite was formed.

The white mica is often found in lozenges ($\frac{1}{2}$ in. by $\frac{1}{4}$ in.) in the body of the granite, and attains in the granite veins the dimensions of 2 in. by 1 in. and even 3 in. ; but, in general, it occurs in plates not exceeding $\frac{1}{10}$th of an inch in diameter. It is Trimetric, occurring either in flat rhombic right prisms, or in hexagonal plates, formed from the former by the replacement of the acute angles ; the angles in all the specimens which I have had an opportunity of examining are exactly 120° and 60°, and I always found the plane of the two optic axes to contain the greater diagonal of the lozenge, joining the acute angles.

The following measurements of the angle between the optic axes may be found useful :—

1. Three Rock Mountain, . .	53° 8′
2. Glendalough, ...	70 4
3. Mount Leinster, ...	72 18
4. Lough Dan, ...	70 0
5. Glenmalure, ...	67 11
6. Poulmounty, ...	76 15

The following analyses show the composition of the white mica of Leinster:—

Table III.

Analyses of White Mica.

	1	2	3	4	Average.
Silica, ...	44·71	44·64	43·47	45·52	44·58
Alumina, ...	31·13	30·18	31·42	35·80	32·13
Peroxide of iron, .	4·69	6·35	4·79	2·16	4·49
Lime, ...	1·09	. . .	1·38	0·67	0·78
Magnesia, . . .	0·90	0·72	1·13	0·29	0·76
Potash, ...	9·91	12·40	10·71	9·68	10·67
Soda, ...	1·27	. . .	1·44	1·08	0·95
Protoxide of iron, .	. . .	. . .	. . .	0·30	0·07
Loss by ignition, .	6·22	5·32	5·43	4·40	5·34
Total, ...	99·92	99·61	99·77	99·90	99·77

1. Glendalough Valley, Co. Wicklow, . Specific gravity = 2·793
2. Mount Leinster, Co. Carlow.
3. Three Rock Mountain, Co. Dublin, „ „ = 2·771
4. Poulmounty, Co. Wexford, in large plates (1¼ in.), silvery white mica.

From the preceding Table we find the following mineralogical results:—

TABLE IV.

Atomic proportions of White Mica.	Atoms.	
Silica, ...	990	
Alumina, ...	618	674
Peroxide of iron, ...	56	
Lime, ...	28	325
Magnesia, ...	38	
Potash, ...	227	
Soda, ...	30	
Protoxide of iron, ...	2	
Water, ...	593	

In the preceding analyses I only determined the quantity of protoxide of iron in the fourth ; but as there is probably a small quantity in the other three, there should be something deducted from the atomic weight of the peroxides, and something added to that of the protoxides; we, therefore, obtain very accurately the following relation for the atomic proportions of silica, peroxides, and protoxides :—

Silica, ...	99, . .	3
Peroxides, . . .	66, . .	2
Protoxides, . . .	33, . .	1
Water, ...	60, . .	2 ?

giving a mineralogical formula for the white mica—

$$\mathrm{RO},\ \mathrm{SiO_3} + 2\,[\mathrm{R_2O_3},\ \mathrm{SiO_3}] + 2\mathrm{HO}. \qquad (3)$$

This is the mica known to mineralogists as Margarodite or pearl mica, and improperly considered by Dana as an altered Muscovite. It is a distinct mineral species, and one highly interesting in connexion with the theory of the origin of granite, as it is undoubtedly a hydrated mineral, not the result of metamorphic action, but coeval with the other minerals forming the mass of the granite.

If its formula be deduced from its oxygen, and not from its atomic proportions, we obtain from the mean of my four analyses—

$$0{\cdot}14\ (3\mathrm{RO}) + 0{\cdot}86\ (\mathrm{R_2O_3}) + 1{\cdot}26\ (\mathrm{SiO_3}),$$

which gives exactly,—

$$\left[\tfrac{1}{7}(3RO) + \tfrac{6}{7}(R_2O_3)\right] SiO_{3}^{\frac{5}{4}} + xHO, \qquad (4)$$

the formula of Dana ; and proves its identity with the mineral described by him as Margarodite.

6. *Black Mica.*—In addition to the white pearl mica, or Margarodite, just described, and which is always found in the granite of the Leinster axis, a variety of black mica is very commonly found in small grains, diffused through the mass of the granite in particular localities, as at Dalkey, Glendalough, and other places.

This black mica is occasionally found in nests, and much more rarely in long crystals, associated with the white mica.

It was discovered in great abundance by my friend and former pupil, Mr. Cotton, C. E., on the cutting of the Bagnalstown and Wexford Railway at Ballyellin, in the county of Carlow. The granite of this locality consists of white orthoclase, quartz, white and black mica, half and half, in long crystals, lying side by side and forming physically the same sheet of mineral, but separated from each other by a well-defined straight line. This line coincides with the trace of the plane of the optic axes of the white mica. The black mica proved on examination to be uniaxal, its optic axis bisecting the angle between the optic axes of the white or biaxal mica. I examined carefully the angle between the optic axes of the white mica associated with the black mica, and found it to vary in different specimens from—

56° 30′ to 71° 0′.

The crystals of black mica are 2 in. by ½ in., and they fit into the crystals of white mica readily, in consequence of the angles of the primary lozenge of the latter being 60° and 120° ; the regular hexagonal base of the black mica crystal fitting, without physical dislocation, into the angles of the white lozenges. At Scalloge Gap, between Mount Leinster and Blackstairs, this black mica is found in nests and lenticular sheets in the fine-grained gneissose granite, which is itself composed of gray quartz, white felspar, and white mica, being a ternary granite, except where the occurrence of the black mica renders it quaternary.

The following analysis gives the chemical composition of the black mica of Ballyellin:—

Table V.

Black Mica of Ballyellin.

	Per-centage.	Atoms.		Oxygen ratio.
Silica, ...	35·55	790		790
Alumina, ...	17·08	328	624	624
Peroxide of iron, . . .	23·70	296		
Lime, ...	0·61	021	538	179
Magnesia, ...	3·07	153		
Potash, ...	9·45	201		
Soda, ...	0·35	011		
Protoxide of iron, . . .	3·55	098		
Protoxide of Manganese, .	1·95	054		
Water, ...	4·30	477		
Total, ...	99·61			

The preceding results were obtained by fluxing with carbonates of soda and potash, and with carbonate of lime and sal ammoniac; and afterwards, on acting upon 10 grs. with hydrochloric acid, it was found to be completely decomposed, giving 35·20 per cent of gelatinous silex. The black mica of Ballyellin is,—

1. Uniaxal.
2. Decomposable by muriatic acid.

From the oxygen ratios of this mica it is easy to deduce the following formula—

$$\left.\begin{matrix}R_2O_3\\3RO\end{matrix}\right\}Si\,O_3 + \tfrac{1}{2}\,HO. \qquad (5)$$

There is no simple relation between the peroxides and protoxides in this analysis; the following is the nearest approach to a formula, founded on their ratio, that I can make—

$$2\,[3RO,\ SiO_3] + 7\,(R_2O_3,\ SiO_3) + 5\,HO. \qquad (6)$$

This formula represents the analysis pretty well, but is not so simple, nor so exact as (5), which I prefer.

The black mica of Ballyellin has been identified by me with the black mica of the granite of Donegal, and is unquestionably a distinct and well-marked mineral species. In most respects it appears to be identical with the Lepidomelane of Soltmann, which is found at Petersberg in Wermland, in small aggregations of minute scales,—a mode of occurrence very common with the black mica of Kingstown, Scalloge Gap, and the black mica of Donegal. Lepidomelane is also soluble in muriatic acid, and is probably uniaxal. Its formula, as analyzed by Soltmann, is—

$$3\,RO,\ SiO_3 + 3\,(R_2O_3,\ SiO_3). \qquad (7)$$

This corresponds with my formula (5), and I believe the two minerals to be the same ; but it is evident that the Irish specimens are much finer and better defined as to their optical properties.

Having thus established the existence of four component minerals, viz., Quartz, Orthoclase, Margarodite, and Lepidomelane, it now remains to examine the composition of the granite as a whole, with a view to determine the relative proportions of each, or the mineralogical analysis of the rock, and also the chemical composition of the felspathic paste remaining after the deduction of the well-defined minerals.

7. *Granite Rock.*—We have now to consider the chemical and mineralogical composition of the granite rock considered as a whole. To the eye it presents a very uniform appearance throughout the whole granitic axis from Rockabill on the north-east, to Poulmounty on the south-west. Quartz, white felspar, and white mica, are always present in distinct grains, and very frequently black mica also, though in a smaller proportion than the white. The following Table contains the analyses of the granite rock, taken as a whole, without separating any of its constituent minerals:—

TABLE VI.

Analyses of Granites of Main Axis.

No.	Silica.	Alumina.	Peroxide of iron.	Lime.	Magnesia.	Potash.	Soda.	Protoxide of iron.	Loss by ignition.	Totals.
1. Rockabill, . .	72·20	16·12	1·82	0·67	0·34	7·92	0·54	0·30	. .	99·91
2. Dalkey, . . .	70·38	12·64	3·16	2·84	0·53	5·90	3·13	. .	1·16	99·74
3. Fox Rock, . .	73·00	13·64	2·44	1·84	0·11	4·21	3·53	. .	1·20	99·97
4. Three Rock, .	70·28	16·44	2·60	2·04	. .	5·79	2·82	. .	. .	99·97
5. Three Rock, .	70·32	16·12	3·20	1·34	. .	4·65	3·39	. .	0·96	99·98
6. Enniskerry, .	74·24	13·64	1·40	1·48	. .	3·95	2·72	. .	1·20	98·63
7. Ballyknocken,	70·82	14·08	3·47	2·65	0·31	4·64	2·31	. .	1·39	99·67
8. Kilballyhugh, .	73·24	15·45	1·60	0·99	. .	4·59	3·08	. .	1·20	100·15
9. Blackstairs, .	73·20	15·48	1·72	0·96	. .	4·80	3·18	. .	. .	99·34
10. Ballyleigh, . .	73·28	12·64	2·00	1·72	. .	4·70	2·97	. .	1·04	98·35
11. Poulmounty, .	71·76	16·68	1·08	1·48	0·28	5·13	2·97	. .	0·60	99·98
Mean, ...	72·07	14·81	2·22	1·63	0·33	5·11	2·79	. .	1·09	100·05

Description of the foregoing Granites.

No. 1. Rockabill, Island off the north coast of the county of Dublin ; the granite forms the foundation of the new Light-house; its existence on this island is not generally known, and it proves the extension northwards of the granitic axis of Leinster. Medium-grained; composed of quartz, white felspar, and small facets of white silvery mica.

No. 2. Dalkey quarries; specific gravity = 2·647; a fine-grained granite, containing both black and white mica. This granite has been used in the construction of Kingstown Harbour.

No. 3. Fox Rock, county of Dublin; specific gravity = 2·638; a coarse-grained granite, striking fire when struck with a hammer, and showing abundant gray quartz.

No. 4. Three Rock Mountain, county of Dublin, Woodside Quarry; specific gravity = 2·652; a coarse-grained granite, containing rhomboidal and hexagonal plates of white mica, speckled with grains of black mica.

No. 5. Three Rock Mountain, county of Dublin; fine-grained granite, with occasional large plates of speckled mica, which appears to be characteristic of the granite of this mountain.

No. 6. Enniskerry, county of Wicklow; specific gravity = 2·633; a rather coarse-grained granite, containing veins of black schorl.

No. 7. Ballyknocken, county of Wicklow, specific gravity = 2·636; a fine-grained durable granite, considered to be the best building-stone near Dublin. The quarries are situated beyond Blessington, county of Wicklow.

No. 8. Kilballyhugh, county of Carlow; specific gravity = 2·616; a fine-grained granite, and a good building-stone; it contains no trace of black mica.

No. 9. Blackstairs Mountain, county of Wexford; specific gravity = 2·622; a medium-grained granite from Kiltealy, on the Wexford slope of Blackstairs Mountain.

No. 10. Ballyleigh, county of Wexford; specific gravity = 2·627; a fine-grained granite, from near Poulmounty Bridge, at the extreme southern boundary of the main granite chain.

No. 11. Poulmounty, extreme south of the granite axis; very fine-grained; quartz, white felspar, and white mica.

If we now take the atomic quotients of the average of the eleven analyses of Table VI., we find the following :—

TABLE VII.

Atomic proportions of Granite of Axis.	Per-centage.	Atoms.	
Silica, ...	72·07	1·601	1·601
Alumina, ...	14·81	0·285	0·313
Peroxide of iron, . .	2·22	0·028	
Lime, ...	1·63	0·058	0·273
Magnesia, ...	0·33	0·016	
Potash, ...	5·11	0·109	
Soda, ...	2·79	0·090	
Loss by ignition, . .	1·09		
Total, ...	100·05		

This Table affords us the means of forming three equations from the atomic quotients of silica, peroxides, and protoxides present in the rock ; as I have shown already (Journal, Geol. Soc. London, vol. xii. p. 178) ; but as we have more than three unknown quantities, we must seek for other equations to determine them ; and in doing so, there is a considerable variety of choice in the methods which might be adopted. We shall first write down the three equations already obtained.

The granite is quinary, or composed of quartz, orthoclase, margarodite, lepidomelane, and felspar paste, having the following mineralogical formulæ:—

1. Quartz,. . . SiO_3.
2. Orthoclase, . $RO, SiO_3 + Al_2O_3, 3 SiO_3$.
3. Margarodite, . $RO, SiO_3 + 2 [R_2O_3, SiO_3] + 2HO$. (8)
4. Lepidomelane, $2 [3RO, SiO_3] + 7 [R_2O_3, SiO_3] + 5HO$.
5. Felspar paste,. Unknown.

We cannot make a single step in the discussion without some assumption as to the felspar paste, which is not known *directly*. The following assumption is most probably correct: that the felspar paste is a tersilicated felspar, having, therefore, the same chemical formula as orthoclase, pericline, and albite ; this assumption I consider nearly certain, from the fact of the presence of abundance of free quartz, which would have converted any monosilicated or bisilicated felspar originally present into a tersilicated felspar, taking its mineralogical character from the predominant alkali.

Let Q, F, M, L, denote the number of atoms of quartz, felspar, margarodite, and lepidomelane present in the granite; from the formulæ of these minerals just given, and from Table VII., we find, as in my former paper,

$$\begin{aligned} 1{\cdot}601 &= Q + 4F + 3M + 9L\,; \\ 0{\cdot}313 &= F + 2M + 7L\,; \\ 0{\cdot}273 &= F + M + 6L. \end{aligned} \tag{A}$$

In these equations we have *four* unknown quantities, and only *three* equations; but a fourth equation may be found as follows :—

Let q, f, m, l denote the per-centages of quartz, felspar, margarodite, and lepidomelane in the granite; then q, f, m, l will be equal to Q, F, M, L respectively multiplied by their atomic weights.

The atomic weights of Q, M, L are known, and may be found as follows :—

The atomic weight of quartz is 45; that of margarodite may be thus found:—

The mineralogical formula of margarodite is in atoms = 3 silica + 2 peroxides + 1 protoxide + 2 water. The atomic weights of silica and water are known, and are 45 and 9 respectively; therefore, if x and y denote the atomic weights of the peroxides and protoxides respectively, we have

$$\text{Atomic weight of margarodite} = 3 \times 45 + 2x + y + 2 \times 9.$$

The values of x and y are found from Tables III. and IV., by the equations,

$$\begin{aligned} 36{\cdot}62 &= 0{\cdot}674 \times x, \\ 13\ 23 &= 0{\cdot}325 \times y. \end{aligned} \tag{9}$$

The left-hand numbers being the *per-centages* of peroxides and protoxides respectively; and the right-hand numerical coefficients denoting the *atomic quotients* of peroxides and protoxides respectively. From these equations we find the values of x and y to be 54 and 40. And finally—

Atomic weight of margarodite $=302$.

The atomic weight of lepidomelane is thus found; its equation in atoms (6), is

9 silica.
7 peroxides.
6 protoxides.
5 water.

If x and y denote, as before, the atomic weights of the compound atoms of peroxides and protoxides, we find from Table V. the following:—

$$\begin{aligned} 40{\cdot}78 &= 0{\cdot}624\,x, \\ 18{\cdot}98 &= 0{\cdot}538\,y; \end{aligned} \tag{10}$$

from which we obtain,

$$\begin{aligned} x &= 65, \\ y &= 35. \end{aligned}$$

And since the atomic weight of lepidomelane is

$$9 \times 45 + 7x + 6y + 5 \times 9\ ;$$

we obtain finally,

Atomic weight of lepidomelane $=1115$.

Using the atomic weights just found, we find the following equations; denoting the unknown atomic weight of the felspar paste, including orthoclase, by ϕ:—

$$\begin{aligned} q &= 45Q, \\ m &= 402M, \\ l &= 1115L, \\ f &= \phi F, \\ q + m + l + f &= 100{\cdot}05\ ; \end{aligned} \tag{B}$$

the last equation being found from the consideration that all the per-centages of constituent minerals, taken together, must make up the entire analysis of the rock given in Tables VI. and VII.

So far as we have hitherto gone, equations (B) add nothing to equations (A), as they are five in number, and contain five unknown quantities in addition to Q, F, M, L, viz., q, f, m, l, ϕ.

Another equation may be found from the consideration that all the iron in the analyses of Table VI. belongs to the black and white micas. White mica contains of iron, Table III., estimated as peroxide, 4·57 per cent., and black mica contains of peroxide of iron, estimating with it the protoxides of iron and manganese, Table V., 29·81 per cent.; while from Table VI., the granite contains 2·22 per cent. If we assume all the iron to belong to the two micas, which is nearly certain, we obtain an additional equation, viz., counting FeO and MnO with peroxides,

$$29{\cdot}81l + 4{\cdot}57m = 222. \qquad \text{(C)}$$

Bringing together all the equations A, B, and C, we have *nine* equations, and *nine* unknown quantities to determine, viz., Q, F, M, L, q, f, m, l, ϕ.

For convenience of solution, it is desirable to set down all the equations together:

$$\left.\begin{array}{rll} 1{\cdot}601 = & Q + 4F + 3M + 9L, & (a) \\ 0{\cdot}313 = & \quad F + 2M + 7L, & (b) \\ 0{\cdot}273 = & \quad F + \ M + 6L, & (c) \\ q = & 45Q, & (d) \\ m = & 402M, & (e) \\ l = & 1115L, & (f) \\ f = & \phi F, & (g) \\ q + m + l + f = & 100{\cdot}05, & (h) \\ 2981l + 457m = & 22200, & (i) \end{array}\right\} \qquad (11)$$

Subtracting (c) from (b), we find

$$0{\cdot}040 = M + L\,;$$

which, by (e) and (f), becomes

$$0{\cdot}040 = \frac{m}{402} + \frac{l}{1115}\,;$$

which, after reduction, gives in combination with (i) the following system for the determination of m and l, the per-centages of margarodite and lepidomelane in the granite:

$$\begin{array}{r} 402l + 1115m = 17929, \\ 2981l + \ 457m = 22200. \end{array} \qquad (12)$$

Solving these equations for l and m, I find, after some numerical reductions,

$$\begin{aligned} m &= 14{\cdot}18, \\ l &= 5{\cdot}27. \end{aligned} \tag{13}$$

From (13), by the aid of (e) and (f), we find

$$\begin{aligned} M &= 0{\cdot}0353, \\ L &= 0{\cdot}0047. \end{aligned} \tag{14}$$

From (14) combined with either (b) or (c), we obtain—

$$F = 0{\cdot}2095. \tag{15}$$

From equations (14) and (15), combined with (a), we find—

$$Q = 0{\cdot}6148\,; \tag{16}$$

with which combining (d), we find—

$$q = 27{\cdot}66 \text{ per cent.} \tag{17}$$

From (13) and (17), with (h), we obtain—

$$f = 52{\cdot}94 \text{ per cent.} \tag{18}$$

And, finally, from (18), (15), and (g), we find—

$$\phi = 253. \tag{19}$$

Bringing together the values of the nine unknown quantities, and the atomic weights known by observation, we have—

$$\begin{array}{ll} q = 27{\cdot}66 & Q = 0{\cdot}6148 \\ f = 52{\cdot}94 & F = 0{\cdot}2095 \\ m = 14{\cdot}18 & L = 0{\cdot}0047 \\ l = 5{\cdot}27 & M = 0{\cdot}0353 \\ \multicolumn{2}{l}{\phi = \text{atomic weight of felspar, } 253.} \end{array} \tag{20}$$

The unknown quantities just determined may be subjected to a severe test by substitution in the original per-centage analysis of the granite, as follows,—

Let $f_{si}, f_{al}, f_i, f_l, f_m, f_p, f_s, f_w,$ denote the unknown proportions of silica, alumina, peroxide of iron, lime, magnesia, potash, soda, and water, belonging to the felspar in the analysis of the granite ; we have the following equations from Tables III., V. and VI., to determine these *eight* unknown magnitudes:—

$$
\begin{aligned}
7207 &= 100\,q + 44{\cdot}58\ m + 35{\cdot}55\ l + f_{si} \\
1481 &= 32{\cdot}13\ m + 17{\cdot}08\ l + f_{al} \\
222 &= 4{\cdot}57\ m + 29{\cdot}81\ l + f_{i} \\
163 &= 0{\cdot}78\ m + 0{\cdot}61\ l + f_{l} \\
33 &= 0{\cdot}76\ m + 3{\cdot}07\ l + f_{m} \\
511 &= 10{\cdot}67\ m + 9{\cdot}45\ l + f_{p} \\
279 &= 0{\cdot}95\ m + 0{\cdot}35\ l + f_{s} \\
109 &= 5{\cdot}34\ m + 4{\cdot}30\ l + f_{w}
\end{aligned}
\qquad (21)
$$

From these equations we may find the following Table, containing the distribution of the various chemical elements of the granite rock among its component minerals :—

Table VIII.

Distribution of Elements among the Granite Minerals.

	Quartz.	Margarodite.	Lepidomelane.	Felspar.	Granite.
Silica, ...	27·66	6·33	1·87	36·21	72·07
Alumina, . . .	. . . . .	4·56	0·90	9·35	14·81
Peroxide, . . .	. . . . .	0·65	1·57	. . . . .	2·22
Lime, ...	. . . . .	0·11	0·03	1·49	1·63
Magnesia, . . .	. . . . .	0·10	0·16	0·07	0·33
Potash, . . .	. . . . .	1·52	0·50	3·09	5·11
Soda, ...	. . . . .	0·14	0·02	2·63	2·79
Water, ...	. . . . .	0·77	0·22	0·10	1·09
Totals, . .	27·66	14·18	5·27	52·94	100·05

Converting the column of felspar into per-centages, we find the following Table, which contains the calculated felspar of the granite, including its orthoclase, which we promised (page 593) to compare with the average result of the various direct experiments made on the felspar of the granite of the Three Rock Mountain. The present calculation gives a slight preponderance of potash over soda in the ratio of 8 : 7, while the direct experiments gave, for the felspar of the Three Rock Mountain, soda in excess of potash in the proportion of 6 : 5. I place most reliance on the numbers contained in Table IX.:—

Table IX.

Calculated Felspar of Granite Rock.

	Per cent.	Atoms.		Oxygen ratio.
Silica, ...	68·40	1·520		1·520
Alumina, . . .	17·66	0·340		0·470
Lime, ...	2·81	0·100	0·390	
Magnesia, . . .	0·13	0·006		
Potash, . . .	5·84	0·124		
Soda, ...	4·97	0·160		
Water, ...	0·19			
Total, ...	100·00			

This Table gives the composition of the felspar of the entire rock, which is a tersilicated felspar, composed partly of orthoclase, and partly of a confused paste, the composition of which cannot be ascertained by experiment, in consequence of the impossibility of separating the orthoclase from it.

The result of the preceding calculations, so far as they relate to the mineralogical composition of the granite, is as follows:—

Table X.

Mineralogical Analysis of Granite.

Quartz, ...	27·66
Felspar (Tersilicate), . . .	52·94
White Mica (Margarodite), .	14·18
Black Mica (Lepidomelane), .	5·27
Total, ...	100·05

The preceding result is, I believe, very accurate, and is, so far as I know, the first exact representation of the composition of a quaternary granite. The granite of Leinster is well suited for a calculation such as I have made, as it constitutes the largest tract of granite in the British Isles, and also retains throughout its extent the greatest sameness of mineral composition.

I shall here add, for the purpose of comparison with the foregoing analyses of the Leinster granites, the following analysis of the granite of Creetown in Scotland, which appears to be the prolongation of the Leinster chain, and resembles in its external appearance many of the Leinster granites :—

TABLE XI.

Creetown Granite.

	Per Cent.
Silica, ...	68·04
Alumina, ...	17·20
Peroxide of Iron, . .	3·15
Lime, ...	2·92
Magnesia, ...	1·20
Potash, ...	3·90
Soda, ...	3·25
Protoxide of Iron, . .	0·41
	100·07

Granite, medium grained; composed of quartz, white felspar, black mica, with occasional specks of white silvery mica. Not unlike specimens from Dalkey.

Although this granite *looks* like the Leinster granites, yet the foregoing analysis is sufficient to prove that it is not the same ; its silica is deficient, and its bases (particularly alumina, lime, and magnesia) are in excess of the average of the Leinster granites.

II.—OUTLYING GRANITIC TRACTS.

1. *General Description.*—We have already given the geological relations, so far as they are known, of the granitic and other igneous rocks which occur in the Cambro-Silurian district of the counties of Wicklow and Wexford, and mentioned the difficulty of explaining the absence of the band of felstones and greenstones over a part of the northern area, while they stretch so continuously across the district on the south.

Over a large part of the district there are a number of outlying granitic patches, occupying a well-marked and characteristic position. These form a series of long granitic islands, following rather the strike or bearing of the beds than the geological boundary of the granite axis, and suggest the idea, which may be collected from the map, that the true axis of the granitic chain lies more to the east of north than would appear from the line of its separation from the slate.

It is impossible to discuss the mineral composition of these outlying granitic patches by the same systematic method that we have applied to the main granite chain itself, as we have the best reasons for believing that they are all formed of that granite, adulterated and mixed with bases, which, varying from place to place, alter the character of the rock in a manner that never occurs in the main chain. We look upon that as the great molten mass, of which the granite islands are offshoots, more or less affected by the bases they have fallen in with in their contact with the slate rocks. The truth of this remark will be best seen from the analyses in the following Table, in which the localities are arranged in order of occurrence, from N. W. to S. E. :—

2.—*Chemical Composition of the Outlying Granitic Tracts.*

TABLE XII.

Composition of the Outlying Granitic Rocks.

	1	2	3	4	5	6	7	8	9
Silica, ...	70·32	63·80	70·80	73·66	80·24	72·40	66·60	68·56	73·96
Alumina, ...	11·24	17·60	18·00	13·64	12·24	17·24	13·26	14·44	12·44
Peroxide of Iron, . .	4·80	3·40	0·80	2·20	0·72	1·60	7·32	5·04	3·07
Lime, ...	3·01	2·70	2·25	0·67	0·89	0·74	3·36	3·85	1·28
Magnesia, ...	0·73	1·00	0·24	0·48	. .	0·43	1·22	0·43	0·14
Potash, ...	2·27	2·61	2·40	4·32	0·40	3·18	2·31	2·78	5·10
Soda, ...	3·39	5·10	4·08	3·51	5·58	3·84	3·60	3·36	3·00
Protoxide of Iron, . .	. .	0·50	. .	. .	. .	. .	. .	. .	0·55
Loss by Ignition, . .	1·62	0·76	1·00	0·72	. .	0·80	2·34	1·00	1·00
Carbonate of Lime, .	1·34								
Totals, . . .	98·72	97·47	99·57	99·29	100·07	100·23	100·01	99·46	100·54

Description of the foregoing Granites.

No. 1. Cushbawn Hill, 1318 ft. high, near Ballynaclash; this granite is the most north-westerly of the granite patches, or nearest to the main granite chain; fine-grained granite, composed of quartz, white felspar, white mica, and green mica; both micas in small grains; specific gravity = 2·671.

No. 2. Coolboy, Tinahely, county of Wicklow; remarkable granitic patch, occupying the bottom of a valley, scored out in consequence of the granite rock being softer than the surrounding slate. The bearing of this granite outlier prolonged to the north-east, as shown on the map, would pass right along the direction of No. 3, or Ballynaclash granite, leaving Cushbawn Hill somewhat to the north-westward. Granite, fine-grained; consisting of—

1. Quartz, gray and minutely disseminated.
2. Black mica, conspicuous, often collecting into flattened nests; 2–3 in. long by 1½ broad, by $\frac{1}{8}$th thick.
3. Very minute specks of white mica..
4. White felspar, saccharoid, intimately mixed with quartz, and semitranslucent.

No. 3. Ballynaclash, on same line as No. 2. Fine-grained granite, composed of—

1. White mica, in small occasional flakes.
2. Dark green hornblendic mica, in minute grains, giving a general greenish character to the rock.
3. Quartz, gray, conchoidal, conspicuous.
4. White opaque felspar, forming the felspathic paste in which the other minerals are embedded.
5. Crystals of felspar, of bright watery lustre, translucent; embedded in 4.

No. 4. Croghan Kinshela, head of Coolbawn brook, N. N. W.; central mass of deep granite of mountain; crystalline; medium-grained; facets of felspar predominating, and giving a character to the rock, which is of a pale-greenish colour, owing to the presence of blackish-green hornblende; the mass is composed of—

1. Quartz, gray, conchoidal, inconspicuous; smothered in felspar.
2. Hornblende in minute grains.
3. Felspar in translucent crystals ($\frac{1}{4}$th by $\frac{1}{8}$th in.), with highly reflecting surface; those crystals, which appear to be orthoclase, give a character to the entire rock.

No. 5. Croghan Kinshela, near summit; specific gravity = 2·629; brilliant white felspar, with gray quartz; stained here and there with patches of chlorite.

No. 6. South Base of Arklow Rock Little; fine-grained granite, very white; it occurs in a vein not more than 20 yds. wide, with slate on each side; composed of—

1. Quartz, distinctly visible in minute grains.
2. Felspar, opaque, very white, forming the greater portion of the rock mass; no distinct crystals.
3. Very minute grains of very silvery white mica disseminated through the rock, giving frequently a silvery lustre to the facets of quartz and felspar.

No. 7. Ballymotymore, near Oulart, containing black mica; specific gravity = 2·659; fine-grained granite.

No. 8. Ballynamuddagh, near Oulart; coarse-grained granite, containing distinct and large plates of black mica, $\frac{3}{10}$th in. broad; specific gravity = 2·670.

Composition of the foregoing Granites—continued.

No. 9. Camaros Hill. This rock appears to contain only two minerals; it weathers into a compact yellowish-white felspar, and has a general resemblance to the granite of Croghan Kinshela, No. 4; it is composed, apparently, of—

1. Felspar of yellowish waxy lustre; facets abundant, not very numerous, set in a paste of yellowish felspar and greenish-black hornblende, intimately mixed.
2. Hornblende in dots, specks, and streaks, mixed with felspar paste.
3. No quartz visible.

Of these isolated granitic patches, the most important, taking into account both area and elevation, are Croghan Kinshela and Camaros Hill (Nos. 4 and 9). It is remarkable that these are the only granites that retain the predominance of potash over soda, that characterizes the granite of the main chain ; and it is worthy of remark, that even in Croghan Kinshela, where the central main mass of the hill retains the character of the original granite that produced it, yet the granite of the summit of the mountain, No. 5, shows a deviation from the mean type of the granitic chain, as great as is presented by any granite in the whole south-east of Ireland. Such an anomaly as this is found nowhere in the granitic chain, where even at Poulmounty, Enniskerry, Three Rock, Dalkey, and other localities within a few yards of the metamorphic slate, the granite of the chain retains its physical and chemical character, uninfluenced by the neighbouring rocks. On the contrary, in the outlying granitic patches no two granites are alike ; some have more alumina ; some, more iron ; some, more lime and soda ; but all differ from each other, and that within the space of a few hundred yards or feet. It would be a hopeless task to investigate the law of composition of rocks so changeable in their character as the granitic island patches of Wexford and Wicklow, and the conclusion is forced upon us irresistibly, from the facts observed, that the only mode of accounting for such a diversity of composition is to assume an equally diverse composition in the aqueous rocks they came in contact with, which have changed and metamorphosed the granite of the main chain into compounds, which, though they are still genuine granite, deviate from it so far as to render it difficult to determine the law of their changes.

3. *Origin of the Outlying Granitic Tracts.*—It is nearly certain that the iso-

lated tracts of granite were formed by the irruption of the granite of the main chain, which granite became mixed up with impurities, consisting principally of bases, and thus degenerated into the separate special forms of granite, the analyses of which are given in Table XII. There is much difficulty in determining the nature and amount of the impurities thus added to the granite of the main chain; but as the subject is one of great importance, I shall make an attempt to exhibit at least the method by which the question should be solved, and trust to further observations to furnish sufficient data for its complete determination.

Let us take, for example, the Coollattin granite, No. 2, and endeavour to determine the amount and kind of admixture with the main granite sufficient to produce it.

Let M represent any arbitrary number of tons of main axis granite, C the unknown number of tons of granite of the composition of No. 2, resulting from the admixture of $C - M$ tons of unknown substances with M tons of molten main chain granite.

It is required to determine the nature and amount of the substances thus added.

It is easy to see the truth of the following equations :—

$$\begin{aligned}
100 \text{ Silica} &= 63{\cdot}80\ C - 72{\cdot}07\ M, \\
100 \text{ Alumina} &= 17{\cdot}60\ C - 14{\cdot}81\ M, \\
100 \text{ Peroxide} &= 3{\cdot}40\ C - 2{\cdot}22\ M, \\
100 \text{ Lime} &= 2{\cdot}70\ C - 1{\cdot}63\ M, \\
100 \text{ Magnesia} &= 1{\cdot}00\ C - 0{\cdot}33\ M, \\
100 \text{ Potash} &= 2{\cdot}61\ C - 5{\cdot}11\ M, \\
100 \text{ Soda} &= 5{\cdot}10\ C - 2{\cdot}79\ M, \\
100 \text{ Loss} &= 3{\cdot}79\ C - 1{\cdot}04\ M.
\end{aligned} \tag{22}$$

In these equations, silica, alumina, &c., stand for the unknown number of tons added to a given number of tons M of main chain granite, to make C tons of Coollattin granite. There is one unknown quantity more than the number of equations. Adding all together, we find, since the silica, alumina, &c., must be equal to $C - M$,

$$100\ (C - M) = 100\ C - 100\ M,$$

which is an identity. We, therefore, cannot obtain an additional equation from the consideration that the sum of the silica, alumina, &c., is equal to the total difference in weight of the new granite and the old.

A number of hypotheses may be made, which would enable us to solve the equations (22). The following are only given as an example of the method of procedure :—

HYPOTHESIS A.—*Let the impurities added to the molten granite equal in weight the mass to which they are added.*

Adopting this hypothesis, which is certainly not a probable one, and taking M equal 100 tons, C becomes 200 tons, and the following values may be found for the elements added :—

TABLE XIII.

Impurities added to 100 *tons of Main Chain Granite, to make up* 200 *tons of Coollattin Granite.*

	Tons.
Silica, ...	55·53
Alumina, ...	20·39
Peroxide, ...	4·58
Lime, ...	3·77
Magnesia, ...	1·67
Potash, ...	0·11
Soda, ...	7·41
Loss, ...	6·54
Total, ...	100·00

HYPOTHESIS B.—*Let the impurities added consist of clay slate and other matters, the ratio of the silica to the alumina being* 90 : 52.

This proportion of silica to alumina is the proportion of two atoms of silica to one of alumina, and is one that is often met with in clay slates.

From it we obtain from the first two of equations (22), the following value :—

$$C = 139{\cdot}2.$$

Substituting this value in the equations, and making M equal 100, we find,—

Table XIV.

Impurities added to 100 *tons of Main Chain Granite, requisite to make Coollattin Granite, on the supposition that a Bisilicate of Alumina is the form in which the Silica and Alumina are added.*

	Tons.
Silica, ...	+ 16·74
Alumina, . . .	+ 9·69
Peroxide, . . .	+ 2·51
Lime, ...	+ 2·12
Magnesia, . . .	+ 1·06
Potash, ...	− 1·46
Soda, ...	+ 4·31
Loss, ...	+ 4·23
Total, . . .	39·20

It follows from this investigation that if the clay slate added to the granite have the composition assumed in Hypothesis B, that part of the potash of the granite must have been washed out before it could have acquired the composition of the Coollattin granite.

In the present state of our knowledge of the substances likely to have been mixed with the granite of the main chain, when it broke through the Cambro-Silurian slates of Wicklow, it would be extremely rash to place any reliance on the foregoing, or, indeed, any other hypothesis. It is to be remembered that the slate through which the granite penetrated is not a basic rock; and, therefore, we find the granite, although altered, still a genuine granite, and the result of Hypothesis B applied to the granite of Coollattin is probable enough. In the Carlingford district, where the rock penetrated by the granite is limestone, the reaction on the granite is very different, as it is converted into a syenite, highly crystalline, composed of anorthite and hornblende.

III. Felspathic and Hornblendic Traps.

1. *General Description.*—In addition to the isolated granite patches already described, which occur through the whole of the Cambro-Silurian rocks of Wicklow and Wexford, there are many other patches of igneous or quasi-

igneous rocks, occurring in well-marked bands in the slates, and apparently contemporaneous with them. They are found in two distinct bands, one to the north, between Arklow and Wicklow; and the other, apparently of the same age, to the south, in a narrow band, lying at each side of a line drawn from Gorey through Waterford to Ballyvoil Head. The following remark on the relative directions of the granite axis, the granite patches, and the trappean deposits, may be useful:—

Granite Axis.	Bearings.
Lugnaquillia to Mount Leinster, . .	29° E. of N.
Kippure to Lugnaquillia, ...	14 „
Kippure to Mount Leinster, . . .	24 „
Mean bearing, . .	22° 20′ E. of N.

The mean direction of the Longmynd system of M. Elie de Beaumont, referred to Milford Haven, is 24° 24′ E. of N.

The Longmynd system is antecedent to the Silurian deposits of Wales.

2. *Granitic and Trappean Patches; Bearings.*—If a line be drawn through the axis of the Coollattin patch, it will pass along the Ballynaclash granite, and if produced southwards will bisect the line joining Stradbally and Kilmacthomas, in the county of Waterford. On the other hand, a line drawn through either Camaros or Oulart granitic patches, in the direction of their axes, will reach the same point.

The first of these lines, which represents the mean direction of the granitic patches of the northern district, is also the mean direction of all the trappean patches, both northern and southern.

The direction of this line is

42° 30′ E. of N.

It does not deviate much from the system of the Hündsruck, which at Milford Haven has the bearing—

48° 48′ E. of N.

It is, perhaps, not merely by accident, that a line drawn from the point half-way between Kilmacthomas and Stradbally to Tuskar Light, passes along the line of junction of the Carnsore granite and the altered slates of the extreme south-east of Ireland. The meaning of these facts is not known, but there is some reason to think that the central point of the eruptive forces that have operated on the south-east of Ireland was situated somewhere in the west of the county of Waterford.

3. *Felstones of the South-East of Ireland.*—The felspathic traps which are associated with the Cambro-Silurian slates of Wicklow, Wexford, and Waterford, were probably contemporaneous with the slates, in which they occur interstratified. They resemble the granite of the main axis in chemical composition, although quite dissimilar in appearance. This resemblance and dissimilarity may be seen from a study of the following Table, and the description of the rocks that accompanies it :—

TABLE XV.

Analyses of Felstones.

	Ballymurtagh. 1	Carrickburn. 2	Bonmahon. 3	Benaunmore. 4	Pitt's Head. 5
Silica, ...	81·36	78·40	77·20	71·52	74·88
Alumina, ...	7·86	11·32	6·54	12·24	12·00
Peroxide of iron, ...	3·32	0·92	5·82	3·16	3·50
Lime, ...	0·99	0·45	Carb. 1·81	0·84	0·34
Magnesia, ...	0·45	0·48	0·60	0·39	1·28
Potash, ...	3·09	4·83	3·69	5·65	4·77
Soda, ...	2·63	3·09	3·03	3·36	2·49
Protoxide of iron, ...	. . .	. . .	. . .	. . .	0·20
Loss by ignition, ...	. . .	0·56	1·12	1·20	1·20
Totals, ...	99·70	100·05	99·81	98·36	100·66

Description of the foregoing Felstones.

No. 1. Bell Rock, Ballymurtagh Mine, Vale of Ovoca, county of Wicklow; from a depth of two or three feet in the rock, obtained by blasting; it weathers white to the depth of a few inches, owing to the kaolinization of its felspar, but the natural colour of the rock is a pale grayish-green; it is exceedingly hard, striking fire freely under the hammer, but, when subjected to the long-continued action of the reducing flame of the blow-pipe, it melts slightly on the edges.

No. 2. Carrickburn, county of Wexford; pale grayish-green felstone, with occasional facets of felspar; weathers quite white; passes in some parts of the mountain into a rock of a nodular, siliceous, concretionary structure, the concretions being 1–3 inches in diameter, and, when broken open, often hollow, or filled with pure quartz and chlorite.

Description of the foregoing Felstones—continued.

No. 3. Bonmahon, county of Waterford; pale greenish felstone, stratified; in other localities in this neighbourhood the felstone is found in columnar masses, sometimes almost translucent on the edges, like the hornstone of the German geologists.

No. 4. Benaunmore, near Glenflesk, county of Kerry; occurs in columnar masses, 200 feet long; it is massive, fine-grained, with rounded specks of quartz (globuliferous) and small occasional facets of felspar, brittle, of conchoidal fracture, somewhat lamellar, and translucent on the edges, with a ringing clink, and striking fire freely when struck with the hammer.

No. 5. Near Pitt's Head, half-way between Caernarvon and Beddgelert, at the summit level of the road, caused by a band of translucent greenish felstone; pale green, semi-translucent, with facets of felspar.

The first three of the foregoing analyses are of rocks from the district under our consideration,—

No. 1. Ballymurtagh, from the north-east extremity of the southern band of felstones.

No. 2. Carrickburn, from the centre of the same band.

No. 3. Bonmahon, from the south-west extremity of the same southern band.

The other two analyses are of rocks similar to the foregoing, but from very different districts:—

No. 4. Benaunmore, near Killarney, associated with beds of the Old Red Sandstone epoch.

No. 5. Pitt's Head, Caernarvonshire; from the lowest Silurians, but above the Lingula beds and magnetico-phosphatic bands of the same county.

The difference between these felstones and the bastard granites associated with them is evident in the relative proportions of potash and soda. The cause was absent, whatever it was (sea water or other cause), that produced the excess of soda above potash, and the felstones of Wicklow, Wexford, Waterford, Kerry, and Caernarvon, are simply potash granites of the ordinary type, that by rapid cooling acquired a stony instead of a crystalline structure, and that appear to be contemporaneous with the beds with which they are associated. The following Table exhibits the true character of these stony granites:—

TABLE XVI.

Atomic Proportions of Felstones.

	Ballymurtagh.	Carrickburn.	Bonmahon.	Benaunmore.	Pitt's Head.
Silica, ...	1·808	1·742	1·715	1·554	1·664
Alumina, . . .	0·151	0·208	0·126	0·238	0·231
Peroxide of Iron, .	0·041	0·011	0·073	0·039	0·044
Lime, ...	0·035	0·015	. . .	0·030	0·012
Magnesia, . . .	0·022	0·024	0·030	0·019	0·064
Potash, ...	0·065	0·102	0·078	0·120	0·101
Soda, ...	0·084	0·099	0·098	0·109	0·080
Protoxide of Iron,	. . .	. . .	. . .	. . .	0·006

From the preceding Table we may deduce the following:—

TABLE XVII.

Atomic Proportions of Silica, Peroxides, and Protoxides of Felstones.

	Ballymurtagh.	Carrickburn.	Bonmahon.	Benaunmore.	Pitt's Head.
Silica, ...	1·808	1·742	1·715	1·554	1·664
Peroxides, . . .	0·192	0·219	0·199	0·277	0·275
Protoxides, . . .	0·206	0·240	0·206	0·278	0·263

From the sensible equality of the atomic proportions of peroxides and protoxides in the preceding Table, it follows that the felstones may be considered as Binary granites, composed of quartz and orthoclase that have cooled rapidly.[*]

The following Table contains their mineralogical composition, calculated on this supposition.

TABLE XVIII.

Mineralogical Composition of Felstones.

	Ballymurtagh.	Carrickburn.	Bonmahon.	Benaunmore.	Pitt's Head.
Quartz, . .	45·54	37·17	40·81	20·51	26·46
Felspar, . .	54·16	62·32	56·07	76·65	73·00
Totals, . . .	99·70	99·49	96·88	97·16	99·46

It is evident from the preceding investigation that there is a very close resemblance between the first three felstones, which occur in the south-east of Ireland. They agree with each other, and differ from the felstones of Kerry and Caernarvon in containing more quartz and less felspar. The average proportions of these minerals per cent. are—

Quartz, . . .	41·72
Felspar, . . .	58·28
	100·00

The felstones of the south of Ireland have been frequently compared to the clinkstones of Auvergne and other volcanic districts. They may be considered as the palæozoic representatives of the clinkstones, but differ from them in several important particulars. Their agreement and difference may be well seen from the following analysis of a clinkstone from Roche Sanadoire, near Mount Dor, collected by Mr. Jukes.

TABLE XIX.

Clinkstone from Roche Sanadoire, near Mount Dor.

	Per cent.
Silica, ...	59·84
Alumina, . . .	18·80
Peroxide of iron, .	2·80
Lime, ...	1·57
Magnesia, . . .	0·23
Potash, ...	5·52
Soda, ...	7·65
Protoxide of iron, .	0·20
Loss by ignition, .	1·62
Total, . . .	98·23

This rock resembles somewhat in its external character the Irish felstones, but its chemical composition and mineralogical constitution is wholly different, as appears from this analysis. The quantity of alumina, and alkalies, particularly soda, is very great, and that of silica is small, as compared with the palæozoic felspathic traps of the counties of Wicklow, Wexford, and Waterford.

4. *Greenstones associated with the Felstones of the South-East of Ireland.*—Although the greater number of the trappean rocks, which occur bedded conformably with the slates of Wicklow, Wexford, and Waterford, are decidedly felspathic in their character, there are found occasionally other rocks which are genuine greenstones, which occur under precisely similar conditions, and are often intimately connected with the felspathic rocks. In fact, one of the most interesting questions connected with the physical geology of this district is the discovery of the precise relation between the greenstones and felstones which are interstratified with the slates of the Cambro-Silurian age. The data for the solution of this question do not yet exist, and the following analyses of two greenstones from the north-eastern extremity of the trappean bands of rock must be regarded as only a first, and that a small contribution, to our knowledge of this subject.

The two specimens analyzed occur close to each other near West Aston, county of Wicklow; and are totally different in physical appearance and character, though probably similar in their origin.

TABLE XX.

Chemical Composition of West Aston Greenstones.

	1	2
Silica,	52·08	57·88
Alumina,	15·60	15·20
Peroxide of iron,	5·75	7·50
Lime,	6·52	4·81
Magnesia,	8·40	6·34
Potash,	3·80	3·03
Soda,	2·92	2·67
Protoxide of iron,	2·57	1·35
Loss by ignition,	2·24	1·04
Total,	99·88	99·82

Description of the foregoing Greenstones.

No. 1. West Aston; dark greenish-gray rock, with glancing surfaces of bronze mica, and alternating parallel faces of felspar of high lustre. It is composed of—
  (*a*) *Felspar*, pale greenish; translucent, with $\frac{1}{2}$ in. irregular shining faces, giving a remarkable aspect to the rock.
  (*b*) *Bronze mica*, faces sometimes $\frac{3}{4}$ in. by $\frac{1}{2}$ in.; presenting the same glancing effect as the crystals of felspar.
No hornblende of any kind visible; the felspar predominates, but the thin flakes of bronze mica are very conspicuous.

No. 2. West Aston; fine-grained crystalline greenstone, into which the rock No. 1 probably passes. It is composed of—
  (*a*) *Felspar*, white, with occasionally a pale greenish tinge; semi-opaque.
  (*b*) *Mica*, rarely white; in minute flakes, passing into a greenish amorphous mineral, apparently in equal quantity with the granular white felspar. It is a leaden-coloured greenish mica, not either hornblende or chlorite.

An inspection of the foregoing analyses is sufficient to prove that these rocks belong to the basic group of igneous rocks. In the absence of all information as to the chemical composition of the separate minerals composing them, it would be impossible to interpret the analyses so as to deduce from them the mineralogical composition of the rocks.

Two different hypotheses may be made respecting these rocks :—

1st. They may be regarded as proceeding from a different molten rock mass from that which produced the granites and felstones of the district. In this case their chemical composition is an ultimate fact, and there is nothing more to be said respecting it.

2nd. They may be regarded as metamorphosed granite, i. e. granite converted into syenitic greenstone by the addition of bases which acted as fluxes. If we knew the bases that were added, or their relation to each other, we should be able to effect the solution of equations similar to (22), established for the Coollattin granite. In the absence of this knowledge, we are driven to use probable hypotheses.

I have already considered two hypothesis (A) and (B), both of which are rendered extremely doubtful from our ignorance of the precise nature of the rock that was added to the molten granite. On the present occasion I shall use a third hypothesis, which is perhaps as improbable as either (A) or (B), but which will serve to bring out prominently the real differences between the granites of the main chain and the greenstones associated with the felspathic traps.

TABLE XXI.

Quantities of Elements to be added to 100 *tons of Main Chain Granite, to convert it into Greenstones of West Aston, No.* 1 *and No.* 2; *on the hypothesis that the Silica remains unchanged in amount during the metamorphism.*

	1	2
	Tons.	Tons.
Silica,	0·00	0·00
Alumina,	6·80	4·19
Peroxide of iron,	5·76	7·15
Lime,	7·39	4·38
Magnesia,	11·29	7·60
Potash,	0·16	- 1·32
Soda,	1·31	0·55
Protoxide of iron,	3·59	1·69
Loss,	2·02	0·20
Total,	38·32	24·44

It is, of course, improbable that nothing but bases could be added to the molten granite, but this supposition will serve to show the striking difference between the greenstone and granite.

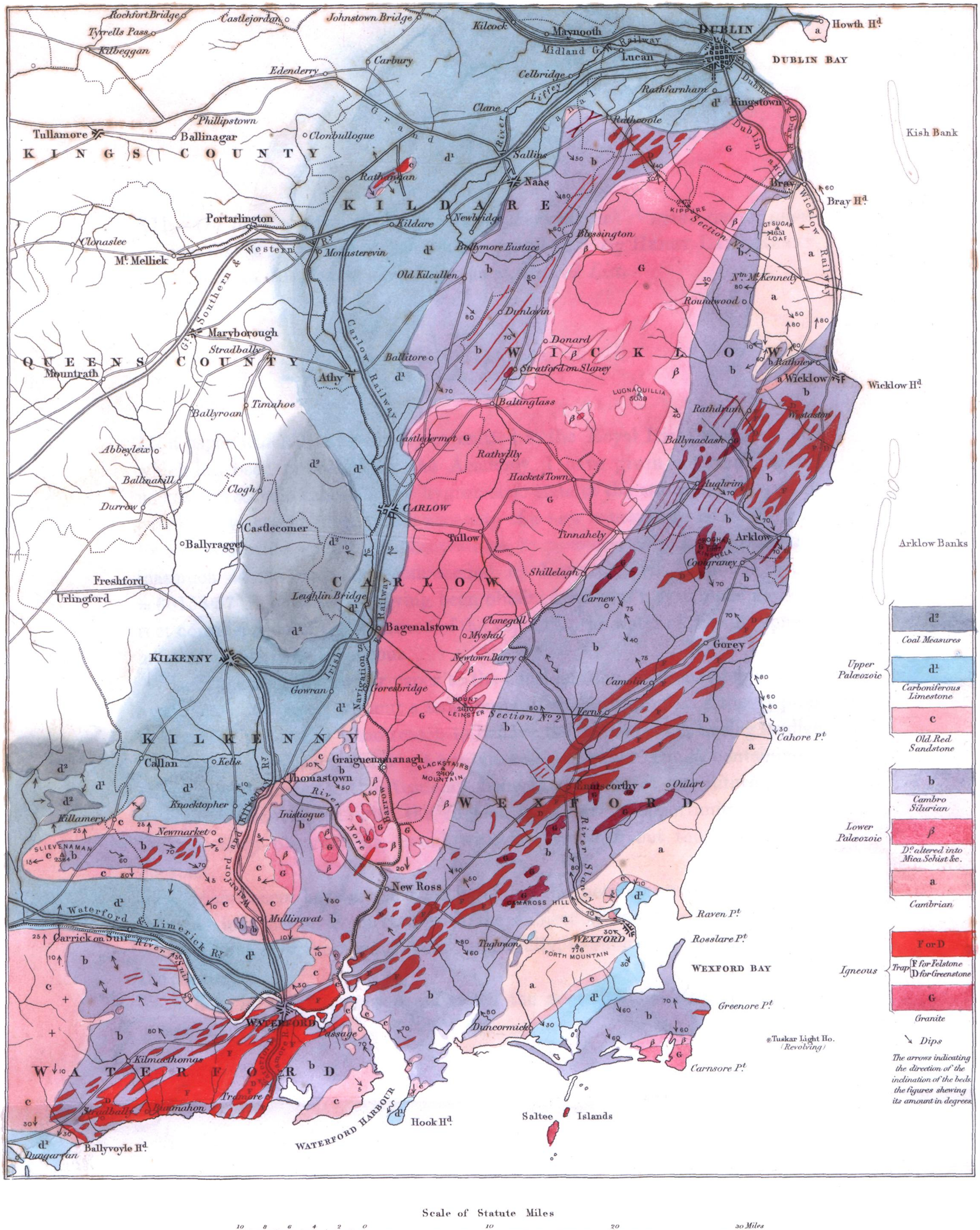
The quantity of lime, magnesia, and iron required to convert the one into the other is especially remarkable, and it is difficult to imagine from what source these bases can have been derived.

On the whole, the relation between the felstones and greenstones, and the origin of the latter, are the desiderata of the physical geology of the igneous rocks of the district; and we would suggest the two following points of inquiry as being well worthy of the attention of geological observers :—

1st. The relations, as to relative position, bedding, intrusion, age, &c., of the hornblendic and felspathic traps of Wicklow, Wexford, and Waterford.

2nd. The chemical composition of the stratified rocks adjoining the outbursts of granite and greenstone throughout the same area, with a view to the determination of the probable metamorphism of the main chain granite into the isolated granites and greenstones by the admixture of such adjoining rocks.—S. H.

GEOLOGICAL MAP
of the LOWER PALÆOZOIC DISTRICT of the
SOUTH EAST OF IRELAND.



Reduced from the published Maps of the Geological Survey of Ireland on the Scale of One Inch to a Mile.